Main Report

Economic Analysis of Devils Lake Alternatives

Prepared for the Corps of Engineers

July 2001

Addendum

To the

Main Report
Economic Analysis of Devils Lake Alternatives
October 2001

The primary purpose of this Addendum to the Main Report is to amend the discussion regarding the Raise Natural Outlet alternative (WF-11). In addition, several other unrelated minor corrections and clarifications are also provided. All of the amendments, corrections, and clarifications are given with the reference to the pertinent section number of the Main Report (to which the reader is referred). Sections of the Main Report that are not referenced need no revision.

Raise Natural Outlet: Revisions

It was assumed in the July 2001 analysis that damages resulting from the Raise Natural Outlet alternative would be limited to damages above the without-project condition peak lake level (1460.6). Further review and discussions regarding the Raise Natural Outlet alternative indicate that it is possible that the Federal government may be required to compensate for all damages above the natural overflow elevation (1459). All features above this elevation would be damaged for a longer duration as a result of the raise, and some of the features that might not have been damaged without the raise may incur damages. Further study was therefore completed and is reported in this Addendum. The revised Raise Natural Outlet alternative analysis considers all damages and feature protection costs above elevation 1459 as project costs.

Results of Alternatives Analysis (Section 1.4)

The revised Table EX-1 (attached) gives results for the updated Raise Natural Outlet alternative.

Calculations of Costs for the Alternatives (Section 3.5)

Paragraph 3, Bullet 8, should be replaced with the following:

- For the Raise the Natural Outlet alternative, land costs between elevations 1459 and 1463

Raise Natural Outlet (Section 4.2.1.3)

The entire section should be revised as follows:

> The annualized costs for implementation of the Raise Natural Outlet alternative total $20.8 million for the 50-year planning period under the Wet Future Scenario. The actual costs of this alternative may differ from those predicted by this analysis if different assumptions are made in estimating compensation for induced damages.

> The Raise Natural Outlet alternative raises the Wet Future Scenario peak lake levels by 2.2 feet as a result of installation of the permanent weir. The downstream impacts, however, are reduced by 22% under the Wet Future Scenario (considering that the existing computed damages remain). Actual downstream impacts from Devils Lake water are eliminated in this alternative.
>
> The annual net benefit of this alternative (using the set of most likely action strategies) equals -
> -$3.5 million. The BCR is 0.83. The net benefits are negative, so the Raise the Natural Outlet alternative is not economically justified under these revised assumptions (using the set of most likely action strategies under the Wet Future Scenario analysis).

Alternatives within the Basin (Section 4.2.4.1)

The entire section should be replaced with the following:

> The Upper Basin Management alternative prevents more damages and avoids more costs than the other alternatives within the basin. Therefore, this alternative has the highest net benefits of the alternatives within the basin.
>
> The Expanded Infrastructure Measures alternative ensures safe protection of the area (raise roads as levees and build perimeter dikes). There is little financial risk with this alternative because the incremental protection measures are completed as required and the project costs are spread over a several-year duration. A limitation of this alternative is that the protection area is restricted to the area within the levee system. There is no assurance that features outside of this levee system will be protected from the rising lake levels. This alternative also has a positive net benefit.
>
> The Raise the Natural Outlet alternative has the only negative net benefits of the alternatives within the basin. This alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level. However, the annual net benefits are completely overwhelmed by the costs for induced damages around the lake (although might vary greatly from those assumed).

Alternatives Within the Basin (Section 6.1.1)

Paragraph 4 should be revised to the following:

> Construction of the Raise Natural Outlet alternative is not economically feasible because of the large expected costs for induced damages adjacent to the lake. This alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level.

Table 7

The revised results for WF-11 are reflected in Table 7; the revised table is attached.

Table 12

The revised information for the revised alternative WF-11 is reflected in the attached Table 12.

Other Corrections and Clarifications

Sensitivity Analysis – Erosion of the Natural Outlet (Section 3.11)

Paragraph 3, Page 37, should be replaced with the following:

> Under this analysis, an annual average peak discharge of 1440 cfs was expected to occur during year 17. (This compares to an annual average peak discharge of only 206 cfs when no erosion of the Tolna Coulee is assumed.) The peak daily discharge with erosion at the outlet was computed to be about 6,000 cfs. With erosion at the outlet, the peak lake level is reduced by 0.17 feet, and the duration of high lake levels is much shorter. Graph 3 compares the lake levels for the Wet Future Scenario when erosion is and is not assumed. As shown by this graph, land adjacent to the lake will be relieved from flooding sooner if erosion occurs at the natural outlet. Therefore, landowners and farmers would be able to return to their land sooner.

Pelican Lake Outlet (Section 4.2.2.2)

Paragraph 1, Page 51, should be replaced with the following:

> The total annual costs for the Pelican Lake 300 cfs constrained outlet alternative are $8.7 million and for the 480 cfs unconstrained outlet alternative are $14.7 million for the 50-year planning period.

Paragraph 5, Pages 51 and 52, should be replaced with the following:

> Using the set of most likely action strategies for local flood protection, the Pelican Lake 300 cfs constrained outlet has a net benefit of $13.2 million, i.e., the annual benefits exceed the annual costs. The BCR is 2.51. The Pelican Lake 480 cfs unconstrained outlet has significantly larger costs and larger benefits, with a net benefit of $15.5 million. The BCR is 2.06. Because the net benefits are positive, the outlet alternatives are economically justified using the set of most likely action local protection strategies according to the Wet Future Scenario analysis. The 480 cfs unconstrained outlet has larger net benefits.

Table EX-1

Table EX-1 was revised to reflect minor corrections for the results for WF-5, Pelican Lake 300 cfs Constrained Outlet.

Tables 6 and 7

The results for Alternatives ST-5, ST-6 and WF-5 were revised to reflect a minor error in the models' computation of the project costs. The attached Tables 6 and 7 reflect these corrections. The corrections do not affect the overall results for the Stochastic Analyses.

Table 9

The information on alternatives M2-3a, M1-3a, and DR-3a have been removed from Table 9. These alternatives are Maximum Infrastructure Protection alternatives that cannot be directly compared to the other alternatives listed in this table.

Table 11

The revised information for ST-5, ST-6, WF-5, and WF-11 and the corrections' effects on the rankings are reflected in the attached Table 11.

Table 12

The revised information for ST-5, ST-6 and WF-5 are reflected in the attached Table 12.

The information on alternatives M2-3a, M1-3a, and DR-3a have also been removed from Table 12. These alternatives are Maximum Infrastructure Protection alternatives that cannot be directly compared to the other alternatives listed in this table.

Table EX-1

Net Benefits and BCRs for Ten Flood Control Alternatives

Description of Alternative	Stochastic Analysis		Wet Future Scenario Analysis	
	Net Benefit (millions)	BCR	Net Benefit (millions)	BCR
Alternatives within the Basin				
Upper Basin Management	-$1.9*	0.29*	$0.5	1.20
Expanded Infrastructure Measures	$1.3	2.10	$0.2	1.06
Raise Natural Outlet	NA	NA	-$3.5	0.83
Outlet Alternatives				
West Bay 300 cfs Constrained Outlet	-$4.2	0.28	$13.3	3.09
West Bay 480 cfs Unconstrained Outlet	-$11.1	0.01	$16.6	2.37
Pelican Lake 300 cfs Constrained Outlet	-$4.9	0.37	$13.2	2.51
Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	0.10	$15.5	2.06
East End 480 cfs Unconstrained Outlet	-$3.8*	0.88*	$18.3	2.85
Combination Alternatives				
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	-$0.6*	0.84*	$0.8	1.13
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	0.46	$14.3	2.28

* The economic indices for these alternatives were computed differently than those of the remainder of the alternatives; downstream impacts were not included. The computed net benefits could be slightly higher or lower than those listed if the computation method had been the same.

Table 6

Comparison of Stochastic Analysis Results
(All dollar amounts in millions)

Analysis Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Adjacent to the Lake: Damages Prevented by Project (%)	Adjacent to the Lake: Costs Avoided by Project (%)	Highest Lake Level[6]	Downstream Damages Avoided[7] (%)	Annual Project Costs[2]	First Costs[3]	BCR
Alternatives within the Basin									
ST-1	Upper Basin Management	-$1.9 [4]	6%	7%	1458	NA	$2.7	$39.7	0.29 [5]
ST-2b	Expanded Infrastructure Measures	$1.3	0%	23%	1458	0%	$1.1	$15.2	2.10
Outlet Alternatives									
ST-3	West Bay 300 cfs Constrained Outlet	-$4.2	10%	13%	1456	1%	$5.8	$71.4	0.28
ST-4	West Bay 480 cfs Unconstrained Outlet	-$11.1	26%	29%	1453	-29%	$11.2	$146.7	0.01
ST-5	Pelican Lake 300 cfs Constrained Outlet	-$4.9	18%	24%	1455	1%	$7.8	$97.1	0.37
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	26%	32%	1453	-20%	$13.8	$182.5	0.10
ST-10	East End 480 cfs Unconstrained Outlet	-$3.8 [4]	26%	29%	1453	NA	$7.2	$47.7	0.88 [5]
Combination Alternatives									
ST-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	-$0.6 [4]	6%	29%	1458	NA	$3.7	$53.7	0.84 [5]
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	14%	38%	1456	1%	$9.4	$133.7	0.46

1. The net benefits listed include the downstream impacts, where available. Downstream impacts are not available for an alternative if the downstream costs and damages were not analyzed for the alternative. Alternatives where downstream impacts are not available are shown with a “4”.
2. Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.
3. First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs.
4. Net Benefits without downstream impacts considered. Actual net benefits would be expected to vary slightly from those shown.
5. Based on benefits without downstream impacts considered. Actual BCRs would be expected to vary slightly from those shown.
6. Based on the 10% probability lake level.
7. The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

Table 7

Comparison of Wet Future Scenario Analysis Results (all dollar amounts in millions)

Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts	Adjacent to the Lake: Damages Prevented by Project (%)	Adjacent to the Lake: Costs Avoided by Project (%)	Highest Lake Level	Downstream Damages Avoided[4] (%)	Annual Project Costs[1]	First Costs[2]	BCR
Alternatives within the Basin									
WF-1	Upper Basin Management	$0.5	5%	6%	1460	4%	$2.7	$39.7	1.20
WF-2b	Expanded Infrastructure Measures	$0.2	0%	11%	1460	0%	$4.1	$54.8	1.06
WF-11	Raise Natural Outlet	-$3.5	17%[5]	-0.16%	1462	22%[3]	$20.8	$311.8	0.83
Outlet Alternatives									
WF-3	West Bay 300 cfs Constrained Outlet	$13.3	32%	39%	1457	19%	$6.4	$71.4	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$16.6	56%	70%	1452	-6%	$12.2	$148.2	2.37
WF-5	Pelican Lake 300 cfs Constrained Outlet	$13.2	33%	45%	1457	19%	$8.7	$97.1	2.51
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$15.5	56%	70%	1452	2%	$14.7	$183.0	2.06
WF-10	East End 480 cfs Unconstrained Outlet	$18.3	56%	70%	1452	-10%	$9.9	$137.8	2.85
Combination Alternatives									
WF-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	$0.8	6%	16%	1460	4%	$6.5	$91.4	1.13
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$14.3	35%	54%	1456	19%	$11.2	$139.4	2.28

1 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.
2 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs.
3 Downstream damages would theoretically be reduced by 100% for this alternative. However, this computation of damages avoided includes remaining flow-related damages that are due to local precipitation events.
4 The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.
5 The percent of adjacent lake damages prevented are a result of a shift of damages to project costs. No adjacent lake features are actually protected by this alternative.

Economic Analysis of Devils Lake Alternatives
Table 9

Comparison of Moderate and Dry Scenarios Results
(costs and benefits in millions of dollars)

Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Damages Prevented by Project[2] (Percent)	Costs Avoided by Project[2] (Percent)	Highest Lake Level	Downstream Damages Avoided[4] (Percent)	Annual Project Costs	First Costs[3]	BCR
Moderate Future 2 Scenario (1455 Peak)									
M2-5	Pelican Lake 300 cfs Constrained Outlet	$3.1	40%	59%	1450	-1%	$8.0	$97.1	1.38
M2-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$0.2	30%	54%	1452	-1%	$10.2	$133.2	0.98
M2-1	West Bay 300 cfs Constrained Outlet	-$0.4	14%	30%	1453	-1%	$5.9	$71.4	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	-$2.8	52%	69%	1448	-44%	$11.7	$148.8	0.76
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	-$3.8	52%	71%	1448	-31%	$14.4	$186.0	0.73
Moderate Future 1 Scenario (1450 Peak)									
M1-5	Pelican Lake 300 cfs Constrained Outlet	-$4.8	61%	45%	1447	-1%	$7.8	$97.1	0.38
M1-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.0	24%	59%	1448	-1%	$8.5	$111.1	0.41
M1-1	West Bay 300 cfs Constrained Outlet	-$5.3	22%	8%	1450	-1%	$5.8	$71.4	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	-$12.1	61%	45%	1447	-26%	$11.4	$149.1	-0.06
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.0	61%	45%	1447	-22%	$13.8	$183.0	-0.01
Dry Future Scenario									
DR-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.9	64%	38%	1448	-2%	$8.4	$111.1	0.30
DR-1	West Bay 300 cfs Constrained Outlet	-$6.0	0%	0%	1448	-3%	$5.8	$71.4	-0.04
DR-5	Pelican Lake 300 cfs Constrained Outlet	-$7.7	0%	6%	1448	-3%	$7.7	$97.1	0.01
DR-2	West Bay 480 cfs Unconstrained Outlet	-$13.6	0%	0%	1448	-33%	$10.8	$142.8	-0.26
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.7	0%	6%	1448	-19%	$13.4	$179.4	-0.10

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Where percentages are shown for "Damages Prevented" and "Costs Avoided", percentages are always based upon the damages or costs that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with a [3].

[2]These damages prevented and costs avoided pertain only to the features adjacent to Devils Lake.

[3]First costs do not include operation and maintenance costs. Natural Resources Mitigation and alternative water treatment are included in first costs.

[4]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the damage category.

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Economic Analysis of Devils Lake Alternatives
Table 11

Comparison of Alternatives
(net benefits in millions of dollars)

Description of Alternative	Stochastic Analysis				Wet Future Analysis				Moderate Future 2 Analysis (1455)				Moderate Future 1 Analysis (1450)				Dry Future Analysis			
	Anaylsis No.	Net Benefit Ranking	Net Benefit[1]	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]
Alternatives within the Basin																				
Upper Basin Management	ST-1	3	-$1.9[2]	6%	WF-1	8	$0.5	5%	--	--	--	--	--	--	--	--	--	--	--	--
Expanded Infrastructure Measures	ST-2b	1	$1.3	0%	WF-2b	9	$0.2	0%	--	--	--	--	--	--	--	--	--	--	--	--
Raise Natural Outlet	--	--	--	--	WF-11	10	-$3.5	0%	--	--	--	--	--	--	--	--	--	--	--	--
Outlet Alternatives																				
West Bay 300 cfs Constrained Outlet	ST-3	5	-$4.2	10%	WF-3	5	$13.3	32%	M2-1	3	-$0.4	14%	M1-1	3	-$5.3	22%	DR-1	2	-$6.0	0%
West Bay 480 cfs Unconstrained Outlet	ST-4	8	-$11.1	26%	WF-4	2	$16.6	56%	M2-2	4	-$2.8	52%	M1-2	4	-$12.1	61%	DR-2	4	-$13.6	0%
Pelican Lake 300 cfs Constrained Outlet	ST-5	6	-$4.9	18%	WF-5	6	$13.2	33%	M2-5	1	$3.1	40%	M1-5	1	-$4.8	61%	DR-5	3	-$7.7	6%
Pelican Lake 480 cfs Unconstrained Outlet	ST-6	9	-$12.4	26%	WF-6	3	$15.0	56%	M2-6	5	-$3.8	52%	M1-6	5	-$14.0	61%	DR-6	5	-$14.7	6%
East End 480 cfs Unconstrained Outlet	ST-10	4	-$3.8[2]	26%	WF-10	1	$18.3	56%	--	--	--	--	--	--	--	--	--	--	--	--
Combination Alternatives																				
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	ST-7b	2	-$0.6[2]	6%	WF-7b	7	$0.8	6%	--	--	--	--	--	--	--	--	--	--	--	--
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	ST-8b	7	-$5.1	14%	WF-8b	4	$14.3	35%	M2-3b	2	-$0.2	30%	M1-3b	2	-$5.0	24%	DR-3b	1	-$5.9	64%

Note: Where percentages are shown for "Flood Damages Reduced", percentages are always based upon the damages that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with a[2].
[2]Net Benefits without downstream impacts considered. Therefore, actual net benefits would be expected to vary from those shown.
[3]These reduced flood damage percentages pertain only to the features adjacent to Devils Lake

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Economic Analysis of Devils Lake Alternatives
Table 12

Alternatives Ranked by Net Benefits
(costs and benefits in millions of dollars)

Analysis/Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Damages Prevented by Project[6] (Percent)	Costs Avoided by Project[6] (Percent)	Highest Lake Level	Downstream Damages Avoided (Percent)	Annual Project Costs	First Costs[2]	BCR
Stochastic Analysis									
ST-2b	Expanded Infrastructure Measures	$1.3	0.4%	23%	1458 [5]	0%	$1.1	$15.2	2.10
ST-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	-$0.6 [3]	6%	29%	1458 [5]	NA	$3.7	$53.7	0.84 [4]
ST-1	Upper Basin Management	-$1.9 [3]	6%	7%	1458 [5]	NA	$2.7	$39.7	0.29 [4]
ST-10	East End 480 cfs Unconstrained Outlet	-$3.8 [3]	26%	29%	1453 [5]	NA	$7.2	$47.7	0.88 [4]
ST-3	West Bay 300 cfs Constrained Outlet	-$4.2	10%	13%	1456 [5]	1%	$5.8	$71.4	0.28
ST-5	Pelican Lake 300 cfs Constrained Outlet	-$4.9	18%	24%	1455 [5]	1%	$7.8	$97.5	0.37
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	14%	38%	1456 [5]	1%	$9.4	$123.9	0.46
ST-4	West Bay 480 cfs Unconstrained Outlet	-$11.1	26%	29%	1453 [5]	-29%	$11.2	$146.7	0.01
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	26%	32%	1453 [5]	-20%	$13.8	$182.7	0.10
Wet Future Scenario									
WF-10	East End 480 cfs Unconstrained Outlet	$18.3	56%	70%	1452	-10%	$9.9	$137.8	2.85
WF-4	West Bay 480 cfs Unconstrained Outlet	$16.6	56%	70%	1452	-6%	$12.2	$148.2	2.37
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$15.5	56%	70%	1452	2%	$14.7	$183.0	2.06
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$14.3	35%	54%	1456	19%	$11.2	$139.4	2.28
WF-5	Pelican Lake 300 cfs Constrained Outlet	$13.2	33%	45%	1457	19%	$8.7	$97.1	2.51
WF-3	West Bay 300 cfs Constrained Outlet	$13.3	32%	39%	1457	19%	$6.4	$71.4	3.09
WF-11	Raise Natural Outlet	-$3.5	17%	0%	1462	22%[7]	$20.8	$311.7	0.83
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$0.8	6%	16%	1460	4%	$6.5	$91.4	1.13
WF-1	Upper Basin Management	$0.5	5%	6%	1460	4%	$2.7	$39.7	1.20
WF-2b	Expanded Infrastructure Measures	$0.2	0.2%	11%	1460	0%	$4.1	$54.8	1.06
Moderate Future 2 Scenario (1455 Peak)									
M2-5	Pelican Lake 300 cfs Constrained Outlet	$3.1	40%	59%	1450	-1%	$8.0	$97.1	1.38
M2-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$0.2	30%	54%	1452	-1%	$10.2	$133.2	0.98
M2-1	West Bay 300 cfs Constrained Outlet	-$0.4	14%	30%	1453	-1%	$5.9	$71.4	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	-$2.8	52%	69%	1448	-44%	$11.7	$148.8	0.76
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	-$3.8	52%	71%	1448	-31%	$14.4	$186.0	0.73
Moderate Future 1 Scenario (1450 Peak)									
M1-5	Pelican Lake 300 cfs Constrained Outlet	-$4.8	61%	45%	1447	-1%	$7.8	$97.1	0.38
M1-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.0	24%	59%	1448	-1%	$8.5	$111.1	0.41
M1-1	West Bay 300 cfs Constrained Outlet	-$5.3	22%	8%	1450	-1%	$5.8	$71.4	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	-$12.1	61%	45%	1447	-26%	$11.4	$149.1	-0.06
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.0	61%	45%	1447	-22%	$13.8	$183.0	-0.01
Dry Future Scenario									
DR-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.9	64%	38%	1448	-2%	$8.4	$111.1	0.30
DR-1	West Bay 300 cfs Constrained Outlet	-$6.0	0%	0%	1448	-3%	$5.8	$71.4	-0.04
DR-5	Pelican Lake 300 cfs Constrained Outlet	-$7.7	0%	6%	1448	-3%	$7.7	$97.1	0.01
DR-2	West Bay 480 cfs Unconstrained Outlet	-$13.6	0%	0%	1448	-33%	$10.8	$142.8	-0.26
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.7	0%	6%	1448	-19%	$13.4	$179.4	-0.10

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Where percentages are shown for "Damages Prevented" and "Costs Avoided", percentages are always based upon the damages or costs that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with a [3].

[2]First costs do not include operation and maintenance costs. Natural Resources Mitigation and alternative water treatment are included in first costs.

[3]Net Benefits without downstream impacts considered. Therefore, actual net benefits would be expected to vary from those shown.

[4]Based on benefits without downstream impacts considered. Actual BCR would be lower than those shown.

[5]Based on the 10% chance lake level.

[6]These damages prevented and costs avoided pertain only to the features adjacent to Devils Lake.

[7]Downstream damages would theoretically be reduced by 100% for this alternative. However, this computation of damages avoided includes remaining flow-related damages that are due to local precipitation events.

Main Report
Economic Analysis of Devils Lake Alternatives

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1.0 Executive Summary

1.1 Motivation for Conducting the Economic Analysis

Flooding at the landlocked basin of Devils Lake has been a problem since the early 1990s. The lake level has risen more than 25 feet since 1993, flooding homes and businesses, roads and railways, and tens of thousands of acres of farmland. Local, State, and Federal agencies have been actively involved in flood control and mitigation efforts for many years. The long-term strategy for dealing with the flooding has been assumed to include some combination of:

1. Upper basin water storage
2. Protection of local structures and infrastructure
3. Construction of an outlet to remove water from the lake

Approval of funding for federal funds for any proposed project is contingent upon reporting regarding the economic justification of the flood management alternative. This Economic Analysis provides a comparison of the economics of several proposed alternatives for managing the Devils Lake flooding.

1.2 General Procedure

For this Economics Analysis, ten flood management alternatives were evaluated—each representing a different combination of storage, protection, and outlet approaches. Each of those ten alternatives was evaluated to determine its cost and benefit.[1] Costs and benefits were used to determine the benefit-cost ratio (BCR) for the project and to compare net benefits. Finally, several of the economic analysis' underlying assumptions were altered, and the costs and benefits were re-evaluated. This was done to determine the sensitivity of the analysis to those underlying assumptions.

1.3 Methodology

Costs for project implementation were determined. It was also necessary to conduct research into the particulars of each of 31 "features"—physical entities (both adjacent to the lake and downstream of the lake) that would potentially be affected by implementation of the alternative. This research allowed formulation of algorithms relating costs and benefits to water level, discharge rates, and river water quality.

For each alternative, 50-year projections of water level were generated based on assumptions regarding future climate conditions and the specifics of each alternative. Based on these water level projections, and on water quality modeling within the Devils Lake basin, both the flow rate and the water quality of any discharge from Devils Lake could be modeled. Combining these projections with hydrologic model

1 For the alternatives evaluated in this Economic Analysis, reduced costs and damages were the project benefits, the reductions occurring as a result of project implementation.

results for the river basins downstream, 50-year projections of flow rates and water quality were made for the downstream rivers (the Sheyenne River and the Red River of the North).

The 50-year projections of lake levels and downstream river conditions were used as input to a computer model that tracked effects on all of the 31 potentially affected features. In this way, costs and benefits for each of the ten alternatives could be projected and averaged over the 50-year period. Comparison of the with-project condition to the without-project condition (taken to be the most likely situation if no project were implemented) allowed calculation of overall project costs and benefits. The model also brought all costs and benefits back to present worth and annualized them, allowing generation of the net benefits and BCR for the alternative.

Projections for the lake levels and downstream river conditions, and for the economic results, vary depending on what assumptions are made regarding climate conditions, flow rates at the natural outlet, and the with- and without-project flood protection efforts around the lake. Two different lake level analyses were conducted: a stochastic analysis that averaged 10,000 different traces and a Wet Future Scenario analysis.

For the sensitivity analysis, these lake level assumptions were altered, and the models were re-run. This resulted in additional sets of alternative-specific 50-year water level and downstream river level projections. These additional sets of 50-year projections were run through the economics model to generate alternate costs, benefits, and BCRs for each alternative. These alternate economic indices were compared to the original indices, allowing an evaluation of the indices' sensitivity to modeling assumptions.

1.4 Results of Alternatives Analysis

The ten alternatives and their computed economic indices are listed below. The economic feasibility of the alternatives varies with the two lake level analyses. In general, if one assumes that the future will be wetter than average, significantly larger net benefits and BCRs result for all the alternatives.

Table EX-1

Net Benefits and BCRs for Ten Flood Control Alternatives

Description of Alternative	Stochastic Analysis		Wet Future Scenario Analysis	
	Net Benefit (millions)	BCR	Net Benefit (millions)	BCR
Alternatives within the Basin				
Upper Basin Management	-$1.9*	0.29*	$0.5	1.20
Expanded Infrastructure Measures	$1.3	2.10	$0.2	1.06
Raise Natural Outlet	NA	NA	$2.4	3.24
Outlet Alternatives				
West Bay 300 cfs Constrained Outlet	-$4.2	0.28	$13.3	3.09
West Bay 480 cfs Unconstrained Outlet	-$11.1	0.01	$16.6	2.37
Pelican Lake 300 cfs Constrained Outlet	-$4.9	0.37	$13.6	2.63
Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	0.10	$15.5	2.06
East End 480 cfs Unconstrained Outlet	-$3.8*	0.88*	$18.3	2.85
Combination Alternatives				
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	-$0.6*	0.84*	$0.8	1.13
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	0.46	$14.3	2.28

* The economic indices for these alternatives were computed differently than those of the remainder of the alternatives; downstream impacts were not included. The computed net benefits could be slightly higher or lower than those listed if the computation method had been the same.

1.5 Results of Sensitivity Analysis

The sensitivity analysis showed that results are sensitive to assumptions made regarding the base level of ongoing flood protection efforts around Devils Lake, to the assumptions regarding future weather patterns, and to the erosion of the natural outlet. (This sensitivity is demonstrated in Graphs 8, 9, and 10, found in the main body of this report.)

The results are highly sensitive to the without-project assumptions—the assumptions regarding the "most likely condition expected to exist in the future in the absence of a proposed water resources project" (National Economic Development criteria). Table EX-1 (above) shows the net benefits for the alternatives when it was assumed that under the without-project condition, the ongoing flood protection efforts (road raises, etc.) around Devils Lake would continue. Net benefits, however, were much larger when it was assumed that the without-project condition would include **no** flood protection around the lake. The larger net benefits are registered because, in effect, the alternative itself is given credit for the flood protection efforts around the lake.

Larger net benefits are also seen when no flood protection is assumed for the features adjacent to Devils Lake (the alternatives can prevent more damages). However, it is unlikely that decision-makers would allow no flood protection, so assuming this for the without-project condition is probably not valid. If a somewhat more likely course of action (implementation of “cost-effective strategies”) is assumed for the without-project flood protection conditions, the resulting net benefits are very similar to those resulting from the original modeling assumptions.

The economic model’s sensitivity to climate assumptions is also very significant. In general, if one assumes that the future will be drier than average, significantly smaller net benefits result for all the alternatives (because there are fewer damages around the lake). The assumption of a wetter future, by contrast, results in larger net benefits (the alternative can prevent more damages). It is also interesting that altering the climate assumptions can change the position in the net benefits ranking for some of the alternatives.

The assumptions regarding erosion of the natural outlet come into play only for those lake futures that rise above the natural overflow elevation. In cases where the lake does overflow, the downstream impacts would be much greater if the natural outlet erodes (resulting in larger net benefits for alternatives that prevent the overflow). The duration of the overflow would be much shorter, but the downstream impacts during the overflow would increase greatly (especially flow-related damages in urban areas).

1.6 Conclusions

The Economic Analysis provides a means by which several flood protection alternatives can be ranked according to standard economic indices. While recognizing the limitations of these indices—they do not account for a variety of social, political, and environmental considerations—the ranking nevertheless allows a comparison of the relative merits of the alternatives. The Economics Analysis also demonstrates that the results are in fact sensitive to the assumptions used for evaluating the alternatives.

This analysis indicates that several of the alternatives are economically justified, with the degree of justification depending somewhat on the modeling assumptions. Under the stochastic analysis, the alternatives within the basin generally compare favorably against the other alternatives. However, if a wet future is assumed, the alternatives within the basin are seen to be less effective; alternatives that include outlets are the most effective alternatives, with a higher (480 cfs) pumping rate favored.

2.0 Introduction

2.1 Project Background

Devils Lake is a closed basin in northeastern North Dakota that receives runoff from a 3,814 square mile watershed. In the seven years between 1993 and 1999, the lake rose over 25 feet, from elevation 1422.5 (feet above mean sea level) in 1993 to a peak elevation of 1447.2 in 1999. In 2001, the lake peaked at elevation 1447.8. Recent lake levels are the highest on record, although the geologic record suggests that the lake has been this high and higher in the distant past.

During the past decade, the lake has expanded from 70 square miles to over 195 square miles. The lake has continued to rise and started overflowing into Stump Lake in 2001. If the lake were to reach elevation 1459, it would be combined with Stump Lake and overflow into the Sheyenne River. The Sheyenne River drains to the Red River of the North.

Rising lake levels have affected communities, transportation routes, and rural lands. Federal, State, and local agencies have adopted a three-part integrated approach to flood damage reduction in response to the rising lake levels. This approach includes:

1. Upper basin water management to reduce the amount of water reaching the lake.
2. Protection to structures and infrastructure in case the lake continues to rise. (Note that "structures and infrastructure" will be referred to as "infrastructure" for the remainder of this report.)
3. An outlet to release some lake water.

2.2 Purpose of Analysis

In 1997, Congress passed Public Laws (PL) 105-18 and 105-62, addressing the emergency outlet. PL 105-18 authorized the U.S. Army Corps of Engineers (Corps) to do planning, engineering, and design for an outlet[2] and to prepare an Environmental Impact Statement (EIS). PL 105-62 set aside funds to initiate construction of an outlet, but final approval is contingent on the Corps reporting to Congress on several issues, including economic justification. These PL 105-62 funds were not sufficient to complete the outlet design and EIS. Supplemental appropriations were allocated in 2000 and 2001 to complete the preconstruction and engineering and design (PED) and associated EIS.

This Economic Analysis of Devils Lake Alternatives (Economic Analysis) responds to the economic justification requirement of the EIS by providing a preliminary economic assessment of alternatives. Figure 1 shows the study area.

2 In this report, an "outlet" is defined as a constructed system by which Devils Lake water can be made to discharge to the Sheyenne River. The outlet could be operated with pumps, or with gravity flow. The term "natural outlet" is used to refer to the existing and naturally-occurring point of discharge from the Stump Lake, and/or the natural channel through which flow would go to the Sheyenne River.

Figure 1

STUDY LOCATION MAP
Devils Lake Limits Study

The purposes of this Economic Analysis are:

- to provide a framework for Federal investment in flood damage reduction alternatives
- to provide information to evaluate the economic feasibility of Devils Lake emergency alternatives
- to evaluate the damages to features adjacent to Devils Lake that are caused by the rising lake
- to explore alternative flood damage responses for communities, roads, rail lines, etc.
- to evaluate the damages to features downstream of Devils Lake—damages that are caused by either a natural overflow or by an outlet

The major effects addressed by this study are physical and economic, i.e., the costs and benefits of the various flood reduction alternatives and their effect on flood protection actions within and downstream of the basin. This study also includes a cursory evaluation of social and environmental impacts of local flood protection measures—measures that might be adopted whether or not an outlet is constructed.

2.3 Organization of Report

An extremely large amount of modeling results was generated during the Economic Analysis, and the analysis itself is extremely complex. To communicate information effectively to a broad spectrum of people, it was necessary to separate the report on the Economic Analysis into three volumes:

- **Main Report**
  The Main Report summarizes the analyses and results of the Economic Analysis. After introductory sections, the report starts by describing the basic approach used to evaluate the economic feasibility of the various alternatives (Section 3). A listing of the economic modeling results, and overall review and comparison of the economic feasibility of the various project alternatives follows (Section 4). Section 5 gives a discussion of how the model results are sensitive to variations in climate assumptions, to assumptions regarding the local infrastructure protection measures, and to assumptions made regarding erosion of the lake's natural outlet. In Section 6, conclusions are drawn regarding the economic feasibility, risks, and effectiveness of the various alternatives.

- **Technical Appendix**
  By comparison to the Main Report, the Technical Appendix gives much more detail regarding the study methodology and results. Table 1 (page 9) presents the organization of the Technical Appendix. Part I of the Technical Appendix describes the methodology and general assumptions used in the detailed evaluation for the Economic Analysis. Data and assumptions used in the analysis of the identified features are included in the Part I appendices. Part II of the Technical Appendix compares the economic feasibility of the various alternatives and evaluates the effects of different lake level futures on the results. Complete detailed results for one flood control alternative are also included in Part II, providing an example of how the costs and damages are computed for individual features.

- **Tabular Data**

  The Tabular Data document provides the detailed tabular results of the various alternatives that were analyzed, grouped by analysis (stochastic and scenario-based). The conclusions of the Economic Analysis are founded on the detailed results presented in the Tabular Data document.

The Main Report and the Technical Appendix both provide a glossary of terms used in the discussions.

Table 1

Technical Appendix Organization

Part I: Methodology			
Introduction			
Analyses	Stochastic Analysis Wet Future Scenario Analysis Moderate and Dry Scenario Analyses		
Alternatives	Alternatives Within the Basin	Upper Basin Management Expanded Infrastructure Measures Raise Natural Outlet	
	Outlet Alternatives	Pelican Lake Outlet West Bay Outlet East End Outlet	
	Combination Alternatives	Combination of Upper Basin Management and Expanded Infrastructure Measures Combination of West Bay Outlet with Upper Basin Management and Expanded Infrastructure Measures	
Methodology for Features Adjacent to Devils Lake			
Methodology for Features Downstream of Devils Lake			
Economic Analysis			
Sensitivity Analyses	Local Flood Protection Strategies Adjacent to the Lake Maximum Infrastructure Protection Adjacent to the Lake Moderate and Dry Future Scenarios Erosion of Natural Outlet		
Attachment I.A:	Devils Lake Outlet Alternatives Screening		
Attachment I.B:	Example Traces Illustrating Various Strategies		
Attachment I.C:	Feature Information:	Features Adjacent to Devils Lake:	Assumptions Decision Trees Logic Flow Diagrams/Algorithms Cost/Damage Tables Inventory Sheets
Attachment I.D:	Feature Information:	Features Downstream of Devils Lake:	Municipal Water Treatment Facilities Industrial Users Irrigation Operations Crops Agricultural Property Urban Areas Transportation Systems
Attachment I.E:	Environmental Mitigation and Monitoring		
Attachment I.F:	Erosion at Natural Outlet		
Part II: Results			
Analysis Results	Stochastic Analysis	Stochastic Analyses Comparison Alternatives within the Basin Outlet Alternatives Combination Alternatives	
	Wet Future Scenario Analysis	Wet Future Scenario Analyses Comparison Alternatives within the Basin Outlet Alternatives Combination Alternatives	
Sensitivity Results	Local Flood Protection Strategies Adjacent to the Lake Maximum Infrastructure Protection Adjacent to the Lake Moderate and Dry Future Scenarios Erosion at Natural Outlet		

3.0 Methodology for Economic Evaluation of Alternatives

3.1 Flood Control Alternatives for Devils Lake

Comprehensive flood reduction evaluations typically analyze a wide variety of flood control projects that either reduce or prevent damages. The intent is to identify the project that provides the largest net benefit. For the Devils Lake basin, the Economic Analysis evaluated a variety of alternatives[3] that could reduce the future lake levels, protect features[4] adjacent to the lake, and/or protect the downstream waters. The range of alternatives that were analyzed included measures strictly within the basin, a variety of outlet configurations, an earthen dike that would prevent any outflow from Devils Lake, and combinations of these. Table 2 lists the ten alternatives that were analyzed.

Table 2

List of Alternatives Analyzed

Alternatives within the Basin
Upper Basin Management
Expanded Infrastructure Measures
Raise Natural Outlet: Natural Overflow Protection
Outlet Alternatives
West Bay 300 cfs Constrained Outlet
West Bay 480 cfs Unconstrained Outlet
Pelican Lake 300 cfs Constrained Outlet
Pelican Lake 480 cfs Unconstrained Outlet
East End 480 cfs Unconstrained Outlet
Combination Alternatives
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures

Following is a description of the alternatives listed in Table 2.

3 The term "alternative" is defined as an overall approach to flood control and management, consisting of a single project or a combination of projects.

4 A "feature" is defined as a physical entity or group of entities that would be susceptible to damage from the rising lake or from flows released from the lake

Alternatives within the Basin

- The Upper Basin Management alternative reduces the flood levels in the Devils Lake by storing water in low areas of the watershed (the "upper basin") tributary to Devils Lake. Easements would be purchased, and structures would be installed to allow water to be ponded in the low-lying areas. The project would make use of approximately 50% of the estimated total available upper basin storage; currently only about 0.5% of the volume is utilized. Implementation of this alternative would require placement of 39,681 acres of land into an upper basin storage program. Note that optimization of benefits by selecting the most effective low areas in the watershed was not attempted as a part of the analysis of the Upper Basin Management alternatives.

- The Expanded Infrastructure Measures alternative examines the economic feasibility of taking additional measures to ensure the safety of flood barriers in areas where roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake in the vicinity of The Narrows. Because these roads are acting as dams, but are not constructed to function as dams, there is a potential safety hazard to road users and to the people living behind and using the areas being sheltered by these barriers. Therefore, for the no-project condition for this alternative, it is assumed that the areas behind these roads would be flooded and subject to damages. The Expanded Infrastructure Measures alternative protects these features under the with-project condition.

- The Raise Natural Outlet alternative evaluates the potential effects of construction of a permanent weir at the natural outlet. The principal goal of such an effort would be to protect the downstream rivers, although the weir would also have the adverse effect of causing lake levels to rise somewhat more quickly at Devils Lake. The weir would prevent a natural overflow up to elevation 1463, but if lake levels rose above this elevation the weir would be overtopped and water would flow to the Sheyenne River. Water overflowing from Devils Lake (with or without the weir) can be expected to be of very poor water quality, and would have adverse effects on the downstream rivers and users of the river water.

Outlet Alternatives

Several alternatives for an outlet were initially evaluated through a screening process conducted by the Corps. Eight basic outlet designs were evaluated for their effectiveness in drawing down the lake levels while simultaneously meeting objectives for downstream channel capacities, water quality criteria, and feasibility for implementation. The report summarizing this initial screening (*Devils Lake Outlet Alternatives Screening*, US Army Corps of Engineers, May 8, 2001) is included in the Technical Appendix. Three of the eight outlet alternatives are included in the Economic Analysis:

- The Pelican Lake Outlet assumes capture and pumping of the fresh water inflow from the Big Coulee (northwest of Devils Lake) before the inflow mixes with the higher salinity water of the West Bay of Devils Lake. Because water from Pelican Lake has relatively low salinity, a higher rate of discharge could be allowed. By comparison to other outlets, this would allow the Pelican Lake outlet to be more effective in drawing down the lake. Of the outlets analyzed, the Pelican Lake outlet would also have the least impacts on downstream features in an unconstrained[5] mode. Two alternatives were evaluated that use the Pelican Lake outlet—a 300 cfs constrained and a 480 cfs unconstrained outlet.

- The West Bay Outlet draws water from the West Bay and pumps it over the divide to the Sheyenne River. Of the sections of Devils Lake relatively near the Sheyenne River, the West Bay has the best water quality. Two alternatives were evaluated that use a West Bay outlet—in one case a 300 cfs constrained outlet, and in the other a 480 cfs unconstrained outlet. The 300 cfs constrained outlet was evaluated in detail in 1998, as the preliminary emergency outlet design (*Devils Lake Emergency Outlet, Independent Assessment, Phase I,* Barr Engineering Company, October 30, 1997).

- The East End Outlet would consist of a grass-lined gravity flow channel that releases water from East Devils Lake into a natural drainage way leading to the Sheyenne River. The east end of Devils Lake is closest to the Sheyenne River, and presents the lowest divide elevation (1465 msl) between Devils Lake and the Sheyenne River basin. Water quality, however, is much worse in East Devils Lake than in the western part of the lake. Nevertheless, the outlet would be relatively inexpensive, and comparably effective (relative to other alternatives) in controlling further rises in lake levels. The channel design would allow 480 cfs to flow out of Devils Lake when the lake elevation is 1446 or higher.

Combination Alternatives

The alternatives listed previously—measures taken strictly within the lake basin, and pumped flow and gravity flow outlets—can be evaluated as separate projects.[6] However, it is possible that a combination of projects may provide more net benefits than an isolated project. Therefore, the following project combinations were analyzed:

- Combination of the Upper Basin Management alternative with the Expanded Infrastructure Measures alternative. The alternative combines storage in the upper basin with expanded flood protection measures to ensure safety of the existing protection measures for features adjacent to the lake.

- Combination of the West Bay 300 cfs constrained outlet with the Upper Basin Management and the Expanded Infrastructure Measures alternatives. In addition to construction of an outlet that directs flow from the West Bay of Devils Lake into the Peterson Coulee, the alternative includes upper basin storage and the expanded flood protection measures that would be implemented to ensure the safety of the existing protection measures for features around the lake. The West Bay outlet was chosen for inclusion in the combination alternative because it has been used in many previous analyses, and has been evaluated previously in Corps planning studies.

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5 An outlet is assumed to be either "constrained" or "unconstrained." A constrained outlet is one for which strict guidelines for discharge are established, controlling the rate of discharge to ensure that Sheyenne River water quality remains within acceptable limits. These limitations are not in force for an "unconstrained" outlet.

6 For this report, a "project" usually refers to a particular flood control measure that reduces the regional damages that would otherwise be caused by the rising lake waters. Note, however, that in the phrase "without-project" or "with-project, " the term project actually refers to an alternative that is being evaluated.

3.2 Benefit/Cost Analysis – General Approach

Evaluation of the economic feasibility of flood control engineering alternatives is a well-established process. At its simplest, the process requires a comparison of the benefits and costs of various projects. The Federal government has formulated standard criteria for calculating the benefits and costs of each project for Federal administrative purposes. These are National Economic Development (NED) procedures. They require comparison of project benefits and project costs[7] at a common point in time. Benefits and costs are considered for the full period of time over which the project would have significant beneficial effects. NED criteria require that benefits and costs must be calculated in terms of an average annual cost (comparable to a loan payment) and an average annual benefit. If the stream of benefits from the project is not greater than the annual costs of the project, the project is not justified economically by NED criteria. This Economic Analysis was based on NED criteria.

In this analysis, both direct and indirect[8] benefits were considered. The benefits of the various alternatives included such items as avoided damages to homes and roads, and reduced expenses for water treatment downstream. Costs of the various alternatives included those for initial project construction, operation and maintenance expenses, and natural resource monitoring and mitigation. (See later sections of this report for a more detailed discussion of costs and benefits for each alternative.) Comparison of the with-project condition to the most likely without-project condition allows calculation of the project's benefits. Benefits take the form of reduced damages and flood protection costs when the project is in place.

For each alternative, the analysis of costs and benefits allowed the computation of the alternative's net benefits and benefit-cost ratio (BCR).

Both the costs and the benefits of the alternatives depend on future lake levels and also on the water quality and water quantity of any outflow from Devils Lake to the Sheyenne River. For every alternative, therefore, the costs and benefits were calculated using two sets of long-term projections—one set of projections regarding the lake levels, and another regarding the water quantity and quality of flows to the Sheyenne River.

In general terms, the steps of the Economic Analysis were as follows:

1. A computer model simulating the hydrology of the Devils Lake basin provided the first set of projections. These 50-year lake level projections resulted from computer-generated patterns of climate fluctuations. The climate fluctuations, along with input parameters related to the specifics of the alternative under consideration, allowed the model to produce 10,000 stochastically-generated

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7 A "benefit" is the defined as the value that is provided by a project or feature protection measure. Cost savings and reduced damages are both tallied as benefits. The "project cost" is defined as the costs related to installation, operation, and maintenance of a project. By contrast, a "cost" is defined as an amount paid to implement a flood protection measure.

8 "Direct" benefits of flood protection measures refer to the benefits of protection from, prevention of, or delay of flood damages to a feature or features. By contrast, "indirect" benefits are those that accrue to a feature by means of avoided costs, or as a consequence of measures taken to protect other features.

50-year “traces” of projected lake levels (see also Section 3.3). Note that for each 50-year with-project trace, it was necessary to produce a companion without-project trace to allow calculation of project costs and benefits.

2. A second computer model was used to give the projections regarding the downstream river water quality and quantity. This second model used the lake level trace output from the first model as input, along with climate projections and hydrologic information for the downstream rivers. In this way, normal river flows could be combined with any Devils Lake outflows to allow prediction of water quality constituent concentrations and flow rates over the same 50-year span (see also Section 3.4). Again, for each with-project trace, a companion without-project trace was generated to allow calculation of project costs and benefits.

3. A third computer program used the lake levels and river water quality and quantity parameters to calculate the costs and damages for each of the features around Devils Lake and for each of those features downstream of the lake that could be affected by outflow from the lake. For each feature, costs and damages were summed for both the with-project and the without-project condition. Subtracting the summations of all the features’ costs and damages with-project totals from the without-project summation of all features’ costs and damages totals allowed calculation of the alternative’s benefits. The project costs compared to these benefits provides the net benefits and BCR for the alternative. Project costs are described in Section 3.5. The processes involved in arriving at the project benefits (costs and damages for the various features) are described in Sections 3.6 through 3.7.

4. Finally, further analysis of the alternative was desired to determine the economic indices’ sensitivity to variations in the assumptions made regarding the alternative. For each alternative, therefore, additional sets of benefits and costs were computed. Each additional set was computed after making adjustments to one or more of the following:

   - Assumptions regarding the future climatic conditions.
   - Assumptions regarding the simultaneous infrastructure protection measures that would be undertaken with or without the project.
   - Assumptions that infrastructure protection measures would be undertaken without the project.
   - Assumptions regarding the way in which the natural outlet would erode if the Devils Lake/Stump Lake system overflowed. (Altering these erosion assumptions changes the flow rate of water spilling from the lake.)

   The sensitivity analysis is described in Sections 3.8 through 3.11.

3.3 Analysis of Lake Levels

A major challenge for evaluating alternatives lies in predicting the future lake levels. Devils Lake is a landlocked lake, so the range of future fluctuations is more difficult to predict than in a simpler system such as a river. Future lake levels are affected by a variety of climatic factors, as well as by the lake level in previous years and the groundwater level. The Economics Analysis evaluated the alternatives using two approaches to defining the future lake levels: a stochastic approach and a Wet Future Scenario approach that is based on recent climatic conditions.

These future lake levels were produced from a lake model created by the United States Geological Survey (USGS). That model created "traces" of future lake levels. Each trace shows a 50-year sequence of lake levels—as an example, Figure 2 shows one trace produced by the model.

Traces of lake levels were first created for the without-project condition. For each alternative that included a project that would affect lake levels (e.g., an outlet, or creation of additional upper basin storage), the model was modified. An additional trace (or set of traces) was then produced to evaluate the effect of the project in lowering lake levels. In this way, every with-project trace (or set of with-project traces) has a companion without-project trace (or set of without-project traces). Figure 3 shows a without-project trace along with a with-project version of the same trace.

3.3.1 Stochastic Analysis

The stochastic analysis determined the likelihood of future lake levels using a large set of possible future lake levels—10,000 traces. The large number of traces was generated as a way of dealing with the uncertainty regarding future lake levels. Because the calculations of the costs and benefits for any alternative depend on the predictions of lake levels, any cost and benefit calculations can be no more reliable than the lake level predictions. The stochastic analysis provides a large number of lake level predictions varying according to fluctuations within reasonable expectations regarding future weather patterns. By computing an alternative's costs and benefits for each of the 10,000 traces, and then averaging those costs and benefits, a reasonable expectation of the cost and benefit for the alternative can be determined.

For the stochastic analysis, every set of 10,000 with-project traces has a companion set of 10,000 without-project traces. Because each trace reflects a particular 50-year projected climate future, each of the 10,000 50-year traces for each alternative is different.

Figure 2
Example Trace
Without Project

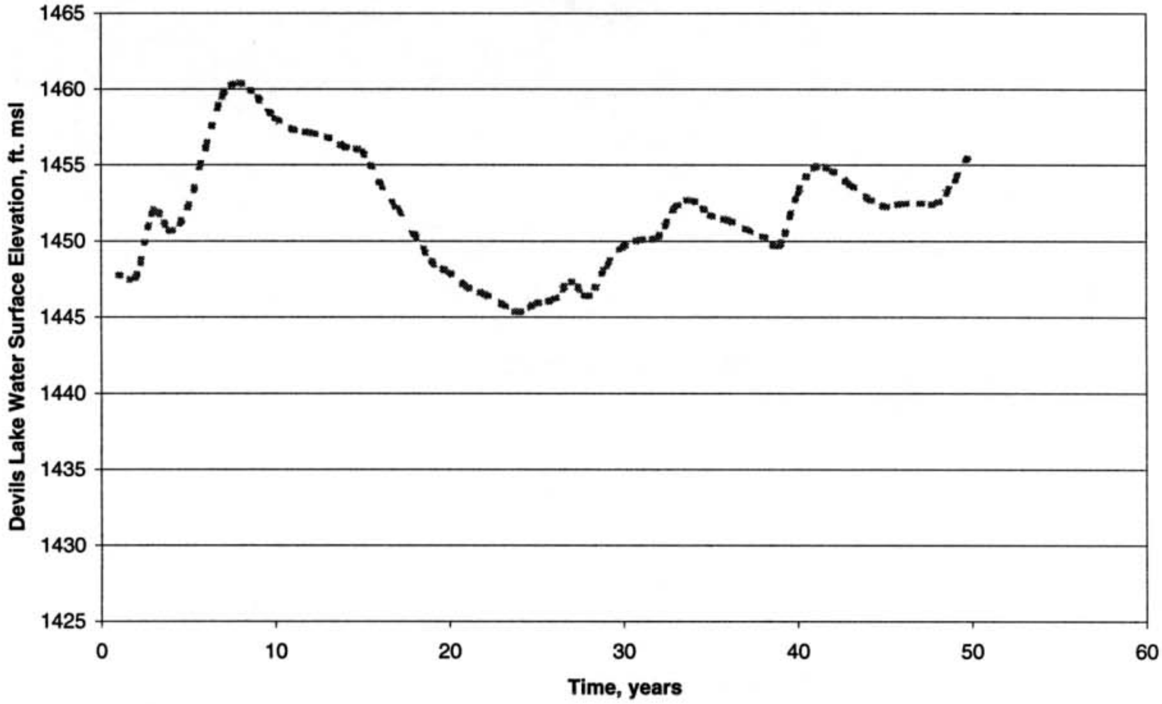
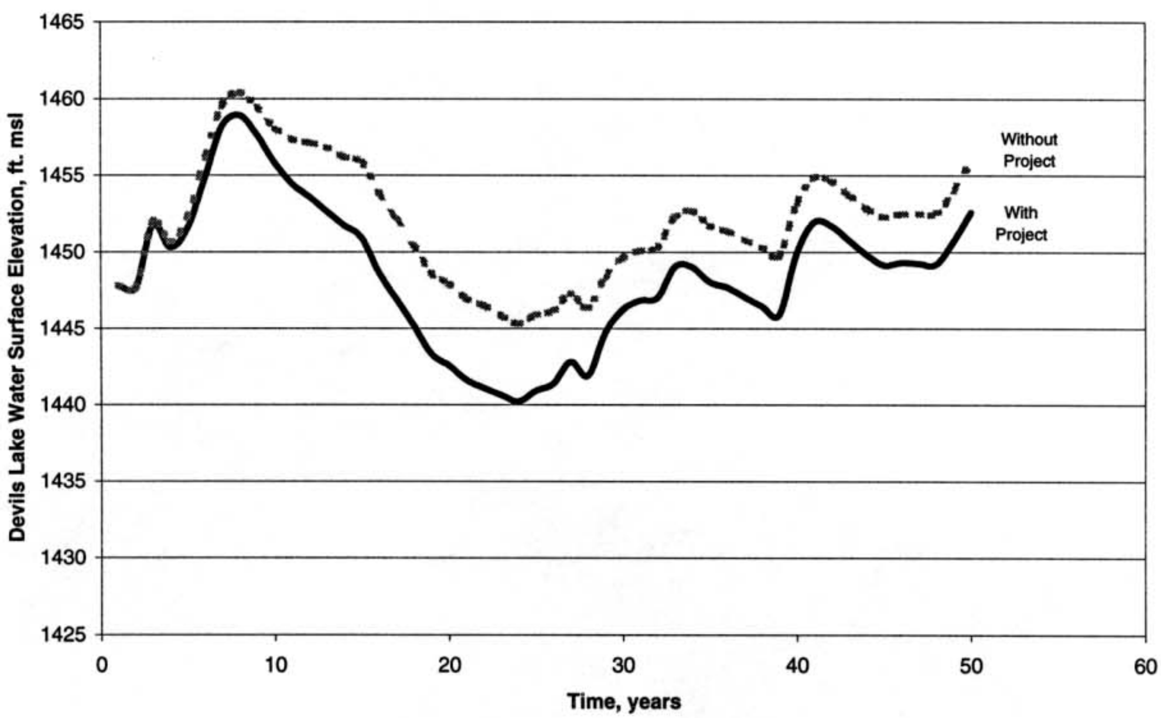


Figure 3
Example Trace
Without and With Project



The first 15 years of the stochastic traces were generated based on the assumption that climatic conditions would be similar to those experienced during 1980-99, reflecting the generally wetter conditions that the Devils Lake Basin has been experiencing since 1980. For the modeling, these conditions were assumed to persist until at least 2015.[9] After 2015, the simulation model assumes that climatic conditions can be represented by the longer historic period 1950-99. The average peak lake level resulting from the stochastic analysis was 1451.7 and the median was 1450.1.

3.3.2 Wet Future Scenario Analysis

The Wet Future Scenario analysis evaluated one set of 50-year lake levels that is based on recent climatic conditions. The Wet Future Scenario repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993–1999) for three cycles, causing the lake to overflow. The remaining years of the 50-year cycle were defined assuming climatic and hydrologic conditions similar to 1980–1999.

The Wet Future trace rises gradually for about 14 years until the natural overflow occurs in year 2014. The lake remains above the natural outlet elevation for about another 11 years. The peak lake level for this scenario occurs in year 19, at an elevation of 1460.6. There is a second peak that occurs near the end of the 50-year period, however, it has a lower peak flood level than the first peak and no additional overflow occurs. By comparison, this wet future is representative of approximately 10% of the stochastic traces, representing those traces that have an average peak lake level of 1461.1.

3.4 Projections of Downstream River Characteristics

A natural overflow or the release of water from the Devils Lake basin will affect the flow rate and water quality of both the Sheyenne River and the Red River of the North. These changes will have impacts on those who use water from those rivers—impacts that need to be counted in the Economic Analysis. Therefore, it is necessary to have projections of the downstream flow rates and water quality to allow assessment of the benefits of any alternative that results in outflow from Devils Lake.

Generation of the 50-year traces of downstream river characteristics was accomplished through use of a lake model that tracks water quality in each of six bays of Devils Lake, using trace data from the lake level model described above as input. Tracking the water quality of the six bays allows determination of the water quality of a discharge from any bay of the lake. The discharge rate is determined based on the pumping rate allowed for a pumped outlet or on the lake level in the case of either a gravity outlet or an overflow at the natural outlet. Projections of discharge water quality and quantity from the lake is integrated with projections for the Sheyenne River and the Red River of the North; the projections based on the same weather conditions assumed for generating the lake level model’s trace data.

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9 This assumption is based on the results of analysis conducted by Leon Osborne, Regional Weather Information Center, University of North Dakota.

3.4.1 Stochastic Analysis

Analysis of downstream river characteristics using sets of 10,000 traces was not feasible for the downstream features. Instead, the downstream features analysis was evaluated for a representative set of four downstream river traces. The four representative traces each correspond to one of four categories of the 10,000 traces—a Wet Future, two Moderate Futures, and a Dry Future—and each trace represents a certain percentage of the 10,000 traces. Using the four traces, therefore, costs and benefits (whether positive or negative) could be determined for each and a weighted average for the downstream features could be determined for each alternative.

As with the portion of the Economic Analysis based on the evaluation of the set of 10,000 lake level traces, each downstream with-project trace must be compared to a corresponding without-project trace to allow a determination of the benefits of the alternative.

3.4.2 Wet Future Scenario Analysis

Downstream river characteristics for the Wet Future Scenario analysis were evaluated directly for each alternative, based on the 50-year trace of downstream water quality and quantity. Again, each downstream with-project trace must be compared to a corresponding without-project trace to allow a determination of the benefits of the alternative.

3.5 Calculations of Costs for the Alternatives

After creating projections for water levels at Devils Lake and for downstream water quality and quantity (for both without-project and with-project conditions), a determination of costs associated with each project is necessary.

Project costs are either fixed or variable. Fixed project costs can be tabulated and summed directly. Variable costs for an alternative must be evaluated by considering each 50-year progression of lake level data or of water quality and water quantity data.

Depending on the alternative, the project costs may include:

- Construction costs for installation of a gravity-flow or pumped-flow outlet, or for a weir that would prevent flow from the natural outlet
- Operating costs for pumped outlet projects during the with-project condition (computed on the basis of the yearly volume of water pumped)
- Maintenance costs during the with-project condition (for pumped outlet projects, assumed to be 1.0% of the first cost during years that the outlet is operating and 0.5% during the years that the outlet is not operating; for gravity outlet projects, assumed to be 1.0% of the first cost annually)
- For Expanded Infrastructure Measures alternatives, costs for the implementation of measures to increase the safety of the existing flood barriers (building roads as levees or building perimeter levees to ensure safe protection of all areas)

- For Expanded Infrastructure Measures alternatives, operating and maintenance costs for levees that protect communities adjacent to the lake
- Upper basin storage program costs (including purchasing easements on 39,681 acres of land, construction of control structures, modifying control structures when the lake recedes, and other associated costs)
- Capital costs for installation of alternate water sources for downstream municipal water treatment facilities that are adversely affected by the project
- For the Raise the Natural Outlet alternative, land costs between elevations 1460.6 and 1463
- Natural resources monitoring (of groundwater levels, riparian vegetation, erosion/sedimentation effects, etc.)
- Mitigation for loss of natural resources and protection of cultural resources

(Note that increased damages resulting from project implementation could also be treated as project costs. For this analysis, however, they are placed on the benefits side of the ledger, and treated as "negative benefits.") The costs that were incurred for each alternative are shown in Table 3. These costs were brought back to present worth and reduced to an annual figure.

Table 3

Costs Incurred for Various Alternatives

Description of Alternative	Costs Incurred (millions of dollars)								
	Construc-tion	Annual Opera-tion	Annual Main-tenance	Safe Protection	Levee O&M	Upper Basin Storage	Alternate Water Source	Annual Environ-mental Monitor-ing	Environ-mental Mitiga-tion
Alternatives within the Basin									
Upper Basin Management						$39.7			
Expanded Infrastructure Measures				X	X				
Raise Natural Outlet	$1.3*								
Outlet Alternatives									
West Bay 300 cfs Constrained Outlet	$58.5	X	X					$0.65	$12.9
West Bay 480 cfs Unconstrained Outlet	$92.2	X	X				X	$0.65	$40.7
Pelican Lake 300 cfs Constrained Outlet	$84.2	X	X					$0.65	$12.9
Pelican Lake 480 cfs Unconstrained Outlet	$129.2	X	X				X	$0.65	$40.7
East End 480 cfs Unconstrained Outlet	$57.4		X				X	$0.65	$40.7
Combination Alternatives									
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures				X	X	$39.7			
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$58.5	X	X	X	X	$39.7	X	$0.65	$12.9

NOTE: Blank spaces in the table indicate that the listed project cost does not apply to the alternative. An X indicates that there is a project cost of the type listed, but that the cost is trace-dependent—subject to variation depending on projections of lake levels or downstream characteristics.

* Costs for the Raise Natural Outlet alternative include construction of the weir ($1.3 million) plus associated damages that are caused by the installation of the weir (the associated damages are variable, dependent on the trace).

3.6 Calculation of Benefits for the Alternatives

The calculation of benefits for the alternatives is more complicated than the calculation of the costs. The following sections explain some of the reasons for the complication, and explain in general terms how the benefit calculations were conducted.

3.6.1 Benefits Evaluation for the Features

The majority of the benefits for the flood control alternatives consist of damages prevented or costs avoided through implementation of a project or projects—with damages occurring both adjacent to and downstream of the lake. Therefore, the evaluation of benefits consists primarily of tabulating flood control damages and costs for both with-project and without-project conditions.

If the damages for a particular feature under without-project conditions exceed those under with-project conditions, the project shows a benefit for protection of that feature. Similarly, if the costs to protect a feature under without-project conditions exceed those under with-project conditions, the project registers a benefit as a result of the cost savings. "Negative benefits" (which in some other analyses might be treated as project costs) occur when damages under with-project conditions exceed the damages under without-project conditions.

Additional benefits for an alternative may be realized through avoidance of costs, as is the case with benefits associated with upper basin storage.

3.6.1.1 Benefits at Features Adjacent to the Lake

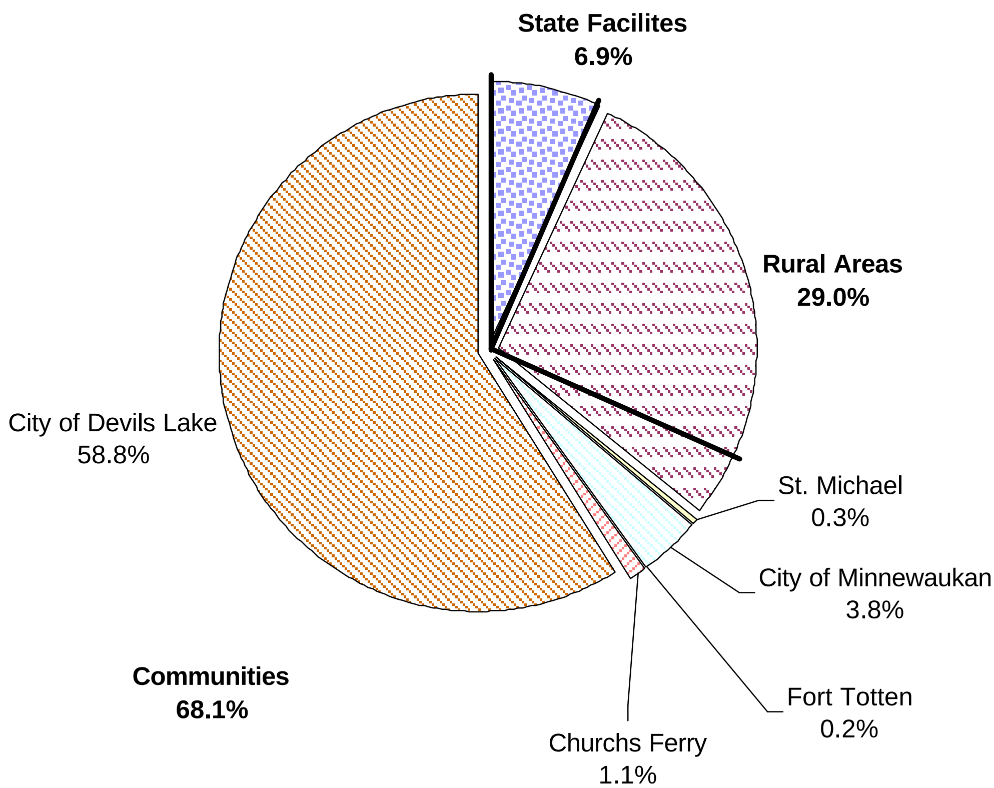
For the features adjacent to the lake, most of the benefits of an alternative come in the form of damages prevented and costs avoided. A reconnaissance-level investigation was completed for each feature adjacent to Devils Lake to determine the damages that would occur if the lake continues to rise. Damages were then computed under both the without-project and with-project conditions for each flood protection alternative. The prevention of flood damages by the project for a particular flood protection alternative was computed by subtracting the with-project damages from the without-project damages.

Note that there are three categories of potential flood damages for features adjacent to the lake:

- Continuously-occurring damages (e.g., detours for vehicles caused by closed roads)
- One-time-only damages (e.g., damages to structures)
- Once-per-event damages, occurring each time the lake rises and falls (e.g., road damages which have to be restored when the lake falls)

These damages all increase as the lake level rises. The continuously occurring damages (detour, trucking, and lost recreational use damages) total over $79 million at the maximum lake level. The one-time-only damages to land and infrastructure total $520 million at the maximum lake level. The allocation of the one-time only damages is shown on Graph 1. The once-per-event restoration damages to roads and rail lines total just over $131 million at the maximum lake level.

Graph 1
Land and Infrastructure Damages
at Maximum Lake Level



Total Land and Infrastructure Damages = $519,141,000

Similar to the evaluation of the damages prevented by the alternative, a reconnaissance-level investigation was completed to define the costs avoided under the with-project condition. These cost savings are a result of reduced flood protection measures within the basin because the project has lowered the lake level. The cost savings and damage reduction computations are described in detail in Sections 3.6.2, 3.6.3, and 3.6.4.

The Economic Analysis does not account for a variety of other flood-related economic impacts, most of which would fall within the Corps' standard damages/benefits called "Regional Economic Damages" (REDs). Prime examples are the impacts of flooding on the region's businesses, and on the $50 million per year recreation industry. These operations are affected by disruptions of the transportation corridors and difficulties with boat access. The business impacts are made worse by exaggerated fears (regarding travel difficulties) of would-be visitors and recreational users of the Devils Lake area.

3.6.1.2 Benefits at Features Downstream of the Lake

For the features downstream of the lake, any benefits of an alternative come in the form of damages avoided. In many cases, however, the alternatives result in "negative benefits" for the downstream features—damages for the with-project condition in excess of those for the without-project condition.

To allow calculation of benefits, therefore, damages were assessed for all downstream features for any alternative under which water is released from Devils Lake. Damages were computed for both the with-project and the without-project conditions.

A total of seven downstream feature types are accounted for in the Economics Analysis. For the downstream features affected by changes in river water quality (the Municipal Water Treatment Facilities, the Industrial Users, and the Irrigation Operations), investigations were completed to allow the development of relationships between water quality and expected damage. For the downstream features that would be affected by changes in flow rates in the rivers (Crops, Agricultural Property, Urban Areas, Transportation Systems), damage estimates are based on information from previous Corps studies.

(Note that other downstream features could be considered. Damages to streambanks, for example, or to aquatic habitat, might be evaluated and added to the tabulation of benefits (whether positive or negative) for a given alternative. Due to the difficulty in establishing cost algorithms relating damage to flow rate for these features, they were not included with the downstream features. Some accounting for the potential damage to such features is made in the Economic Analysis, however, by including the costs for environmental damage and mitigation in the project costs.)

There are two general categories of damages to features downstream of Devils Lake:

- Continuously-occurring damages, e.g., increased water treatment costs as a result of higher salinity
- Recurring (once per year) damages, e.g., flow-related damages to crops, transportation, and/or structures)

3.6.1.3 Benefits Associated with Upper Basin Storage

A project may provide benefits as a result of the conditions of the Upper Basin Storage programs. These programs are currently configured to provide 800 acre-feet of storage in upland areas when water levels exceed elevation 1440. These programs are assumed to remain in effect for both without- and with-project conditions. Where these upland areas are used for flood storage, easement payments are made to compensate landowners for the loss of use of their land. If a project results in lake elevations falling below 1440, the land could be returned to productive use. The elimination of the need for payment is represented as a reduction in damages as a result of the project, and is registered as a benefit.

The lake level traces were analyzed for both the with-project and without-project conditions to determine in which years the Upper Basin Storage programs would be used, and in which years they would be discontinued. For years in which the storage payments were removed, the savings were recorded as a benefit for the project. Savings were brought back to present worth according to standard economic practices.

3.6.2 Benefits and the Components of Devils Lake Flood Control Effort

This economic modeling effort is complicated by the need to take into account ongoing flood control activities around Devils Lake, touched upon in Section 3.6.1.1. The responsible agencies—Federal, State and local—are pursuing an integrated approach to flood damage reduction. The three major parts of this approach are:

1. Local flood protection using measures (or “strategies”) such as levee construction and road raises
2. Upper basin storage to reduce the amount of water reaching the lake
3. Projects to release some lake water, prevent natural overflows, or augment upper basin storage

The first two parts of the flood damage reduction are already underway and ongoing, and can be expected to continue whether or not any projects are initiated. This observation is noteworthy because it affects the assumptions regarding the without-project condition.

In typical economic analyses, the without-project condition is generally thought of as the “no-action plan.” More formally, however, the without-project condition is taken as the condition most likely to exist in the future without a project. At Devils Lake, this will always include some of the ongoing flood control efforts (parts 1 and 2 above). This fact complicates the analysis, and means that the analysis of benefits must always be completed for a companion without-project trace when a with-project trace is analyzed.

The following table shows the characteristics of the without-project and with-project conditions.

Table 4

Components of the Without-Project and With-Project Conditions

Without-Project Condition		With-Project Condition		
1. Upper Basin Storage	**2. Infrastructure Strategies**	**1. Upper Basin Storage**	**2. Infrastructure Strategies**	**3. Project or Combination of Projects**
800 acre-feet when lake is at or above elevation 1440	**Communities:** Levees, Relocations	800 acre-feet when lake is at or above elevation 1440; Additional storage may be provided under some alternatives	**Communities:** Levees, Relocations	Various Alternatives (For example: West Bay Outlet, Flow Rate of 300 cfs constrained)
	Rail Lines: Raises, Closures		**Rail Lines:** Raises, Closures	
	Roads: Raises, Reroutes, Closures		**Roads:** Raises, Reroutes, Closures	
	Rural Areas: Relocations, Abandon lands		**Rural Areas:** Relocations, Abandon lands	

Providing upper basin storage and flood protection for features adjacent to Devils Lake are ongoing major efforts, and in most cases would be affected by a project. Determining the benefits of a project must therefore include:

1. Evaluation of the direct benefits resulting from prevention or delay of flood damages (because the outlet would slow the lake's rise and/or keep it from reaching higher levels).
2. Evaluation of the indirect benefits from a reduction in the number of years that the upper basin storage programs would be used (because the outlet would reduce the number of years that the lake would be at or above the trigger level for the upper basin storage program).
3. Evaluation of the direct benefits from protection to features adjacent to Devils Lake (the project could include building levees or raising roads as levees).
4. Evaluation of the indirect benefits of cost savings from postponed, reduced, or avoided local flood protection such as levees or road raises (because the outlet would slow the lake's rise and/or keep it from reaching higher levels altogether).

In addition to these project benefits, the impacts to features downstream of the lake must be included (Section 3.6.1.2).

3.6.3 Assumptions Regarding Flood Protection Adjacent to Devils Lake: The Most Likely Action Strategy

Evaluating the effects of local flood protection is difficult, because there is no comprehensive plan for flood protection for the Devils Lake area. However, assumptions were necessary in order to compute the associated benefits, as described in Section 3.6.1.1.

The locations where flood damages might occur were analyzed at 24 separate features adjacent to the lake. They include communities, roads, rail lines, public facilities, and rural areas. The features are listed below (Table 5) and their locations are shown on Figure 4.

Table 5

List of Features Adjacent to Devils Lake

Communities and Cities (includes wastewater treatment facilities, hospitals and schools)
1. Churchs Ferry
2. City of Devils Lake
3. Fort Totten
4. City of Minnewaukan
5. St. Michael

State Facilities
6. Gilbert C. Grafton State Military Reservation
7. Grahams Island State Park

Rural Areas
8.1 Devils Lake Rural Areas
8.2 Stump Lake Rural Areas

Rail Lines
9. Red River Valley and Western Railroad: Minnewaukan South (note: this rail line has been abandoned)
10. Canadian Pacific Railroad: City of Devils Lake to Harlowe
11. Burlington Northern Railroad: Along US Highway 2
12. Burlington Northern Railroad: Churchs Ferry to Cando

Roads
13. US Highway 2
14. Highway 57 between Highway 20 and BIA 1
15. Highway 57 between BIA 1 and Highway 281
16. Highway 281 South of US Highway 2
17. Highway 281 North of US Highway 2
18. Highway 19 from the City of Devils Lake Levee to Highway 281
19. Highway 1
20. Highway 20 North of the City of Devils Lake
21. Highway 20 from the City of Devils Lake Levee to Highway 57
22. Highway 20 between Highway 57 and Tokio
23. BIA 1 between Highway 57 and BIA 6
24. BIA 6 between Highway 20 and Fort Totten

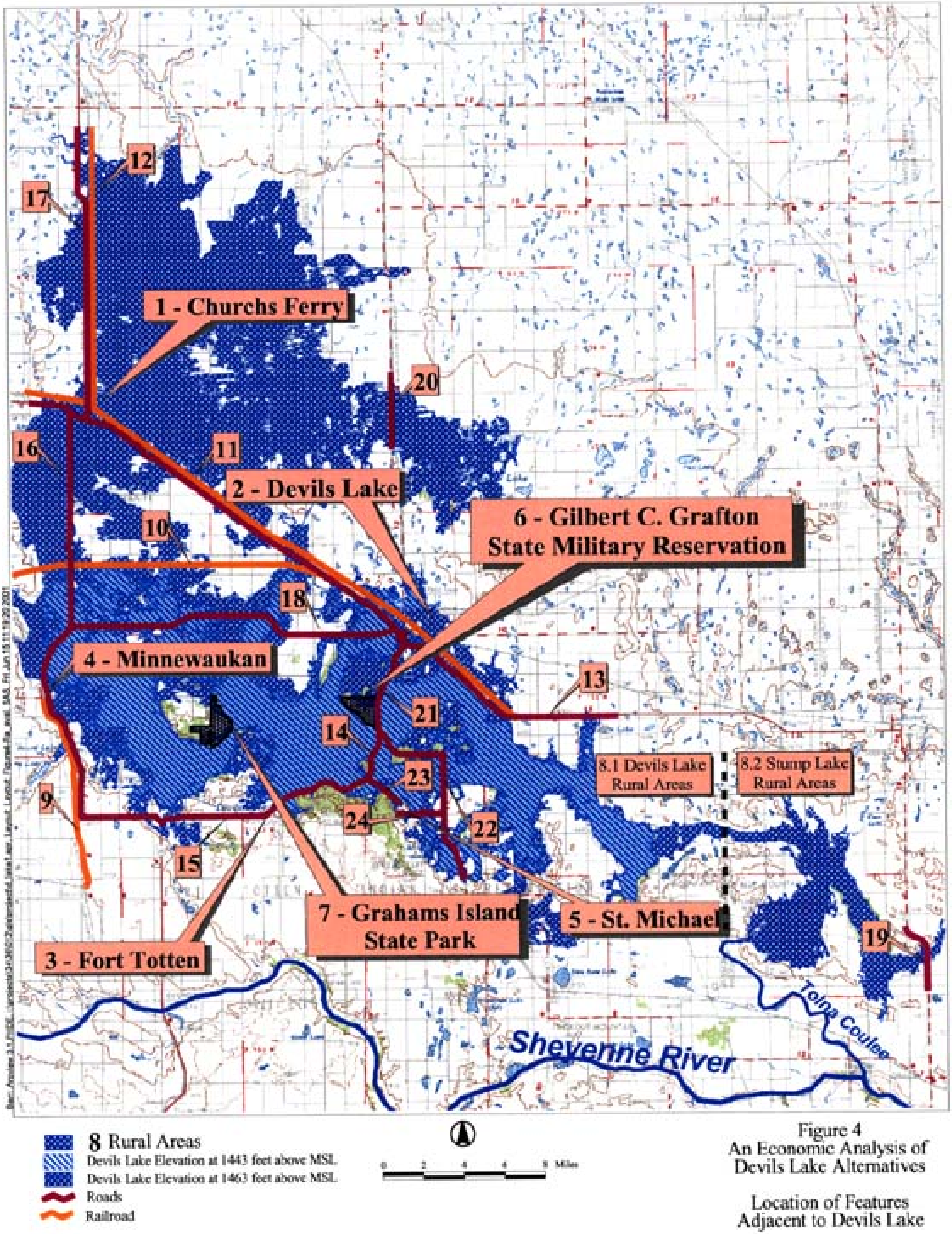


Figure 4
An Economic Analysis of Devils Lake Alternatives

Location of Features Adjacent to Devils Lake

For each separate feature, a variety of different flood protection measures (called "strategies") could be implemented. Various strategies could be implemented to protect any given feature; a community, for instance, could be protected by building a levee or by relocating flood-prone buildings. Furthermore, a levee could be constructed as one large project or as a series of smaller projects when needed. Relocation of homes or businesses could take place at once, or in a series of incremental relocations. And hybrid strategies could include relocation of some structures at low elevations and construction of a levee at a higher elevation to protect the remaining structures in the community. In addition to the above types of strategies, a strategy that assumed no flood protection was also included for all features. Any of the list of strategies would be conceivable for a particular feature. The types of strategies analyzed for the features are described in further detail in Section 3.6.4.

In the absence of an established overall plan, it was necessary to make assumptions regarding the local strategies that might be implemented for each feature. It should be noted that these assumptions could significantly affect the estimated economic feasibility of a project. For instance, if local flood protection efforts (e.g., levees) are highly effective, a project might not produce many additional benefits. On the other hand, if it were assumed that no local flood protection was implemented, the emergency project would have a large impact on reducing damages and would itself produce many benefits because it would be the only flood protection measure in operation. These examples are extreme, but they show that it is necessary to use a consistent rule in making assumptions about local flood protection efforts.

In calculating NED benefits, the general rule used in making assumptions about local flood protection was to assume that the *most likely actions* regarding local flood protection measures would be implemented (with or without a project). The types of emergency measures that are currently being pursued in the basin were assumed to continue to be implemented whenever they are necessary as the lake continues to rise. This set of *most likely actions* was assumed to be the without-project condition for most alternatives evaluated in this study, meeting the National Economic Development (NED) criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project."

It is important to note that the assumption of *most likely actions* regarding local flood protection measures is only made for the purposes of computing NED benefits, and is not a proposed plan of action or a prediction of what local officials may actually implement. Other strategies may actually be implemented for a particular feature because of funding limitations, for environmental or social reasons, or if the lake rises faster than measures can be implemented.

For each feature, the analysis evaluated a wide range of strategies for both the with-project and without-project conditions. The costs to implement each strategy and the associated damages were expressed as a function of lake level and used as input to the economic modeling program (Features Analysis Model). For each 50-year trace of lake levels, the model accounted for the appropriate flood protection costs and associated damages at each feature. For each trace, the 50 years of costs and damages were then converted to a present worth value and an average annual cost or damage. The analysis computes the annual costs and damages for that trace for the most likely strategies. This process was repeated under both the with-project and without-project conditions.

For the stochastic analysis, this process was repeated 10,000 times for the most likely action strategy to evaluate the full range of possible 50-year futures without a project. The average of the 10,000 average annual values produced from these traces represents the (overall) average annual value for costs and damages for the without-project condition. To provide comparable data for the with-project condition, the entire analysis of the most likely action strategy was then repeated using the 10,000 with-project traces. The average of the 10,000 average annual values produced from these traces represents the (overall) average annual values for costs and damages for the with-project condition.

Similarly, the process was completed for all other feature protection strategies as a sensitivity analysis. This comprehensive analysis of local flood protection measures was necessary to evaluate the assumptions for analyzing the benefits of the projects. However, it also produced information regarding local flood protection efforts that may prove useful and informative regardless of the decision made regarding the project. The following section contains more detail on the analysis of benefits derived from savings in local flood protection costs.

3.6.4 Cost Savings in Local Flood Protection Measures Adjacent to the Lake

To calculate the cost savings in local flood protection measures that would be provided by each alternative, the analysis had to make assumptions regarding the most likely action measures that would be used and evaluate the costs of such measures over the full range of possible future flooding probabilities. This approach was described above in general terms. A reconnaissance-level investigation of the costs associated with various flood protection measures (such as levees or road raises) was used to compute the cost savings of the project. The costs of these flood protection measures were computed using a simulation model (Feature Analysis Model) under both the without-project and with-project conditions. The reduction in costs from postponed, reduced, or avoided flood protection may occur if the project slows the lake rise and/or keeps it from reaching higher levels. The most likely action strategies for flood protection were selected from within these measures that were evaluated. The other strategies were used to evaluate the sensitivity of the analysis to these strategies (Section 3.8).

To date, there has been no definitive conclusion on which flood protection strategies are most appropriate for any given feature at Devils Lake. The study provides resolution of this issue by a reconnaissance-level investigation of the following strategies for flood protection of individual features:

- **No Flood Protection**
  The no flood protection strategy assumes that no efforts are made to provide flood relief for a feature. While this may seem unrealistic in terms of intent, it is possible that flood relief might not be provided if emergency assistance would come too late to succeed, or if it were be restricted due to lack of funds.

  Every feature has at least one type of no protection strategy, incremental strategy, and maximum protection strategy. However, achieving flood protection for all of the features would involve significant cost, whether one employs incremental or maximum protection strategies. The local, State and/or Federal governments may not have the resources to finance flood protection of all features. As a result, and because of the large number of features affected by the rising lake level in recent years, the no protection strategy has been adopted for many features around the lake. For example, many of the roads have been abandoned in recent years and portions of them are now under water (Minnewaukan Flats Road, Township road to Grahams Island from the south, Township road across Black Tiger Bay, etc.).

- **Incremental Protection**
  Incremental protection strategies are those that provide flood protection in a series of small elevation increments, such as raising a levee or a road 5 feet at a time. For a community, relocation of structures can also be done as an incremental protection strategy if it is done in small increments, relocating groups of flood-prone homes and structures in accordance with changes in the lake water level. These strategies can be very cost-effective because they provide protection for a majority of the future flooding events on an as-needed basis.

  During the current emergency, the incremental approach to flood protection has been used for many of the features analyzed in this study. Incremental protection strategies are easier to implement than maximum protection strategies because each increment is relatively low in cost and, therefore, easier to fund for local and State governments. However, the funding for incremental protection strategies requires continued approval, magnifying the ongoing stress of the flooding problem. In addition, the incremental approach is based on the widespread hope that the lake level will peak and start to decrease, potentially eliminating actions at higher lake levels. The total cost for implementation of incremental protection may in fact be greater than one-time protection because of the additional project planning, management, and mobilization/demobilization costs.

- **Maximum Protection (at the First Decision/Action Level)**
  One-step strategies are designated "maximum protection strategies" because no subsequent actions would be necessary for that feature even if the lake should rise to its potential maximum elevation of 1463. These strategies would include relocating portions of a community that would be threatened by the lake's maximum elevation, raising a levee to protect a community against the lake's maximum elevation, or raising or rerouting a road or rail line to a new alignment above the lake's maximum level. These strategies are generally not cost-effective, but were included in the analysis mainly as a test of the sensitivity of the analysis to an extreme assumption. The strategy assumes that the protection measure would be incurred at the first decision/action level.

  Maximum protection strategies of road raises, road relocations, railroad raises, structure relocations, and levee raises can be considered to be feasible. However, it should be recognized that a "one-step" raise for all features at once would be extremely costly. It also might prove to be a poor investment if the lake never reached the maximum lake level. Nevertheless, it is possible that a maximum protection strategy may have a greater net benefit over the long run than an incremental strategy that requires a series of projects. The one-step approach would also eliminate the need to continually revisit decisions on funding.

- **Hybrid**
  It is also possible to institute hybrid strategies that are a combination of the incremental and maximum protection strategies. For example, a plan could call for initially raising a road in one 5-foot increment (incremental protection strategy). Then, if water levels continue to rise, the plan could call for rerouting the road (maximum protection strategy).

  Hybrid strategies have advantages and disadvantages similar to the incremental strategies at the lower action levels, and advantages and disadvantages similar to the maximum protection strategies at higher action levels. If the lake level never reaches the action level where the maximum protection step is implemented, the hybrid strategy terminates at the last incremental strategy step.

3.6.5 Downstream Feature Protection/Mitigation Assumptions

An accounting for mitigation of some of the deleterious environmental effects of projects is included in the project costs for those alternatives that involve discharge to the Sheyenne River. However, no protection is assumed for any of the seven downstream features considered in the Economic Analysis. The economics of these features are generally accounted for solely in terms of damages incurred, resulting in either positive or negative benefits for the alternative.

3.7 Calculation of Benefits

As discussed above in Section 3.6.3, one set of flood protection strategies—the set of most likely action strategies—was assumed to be in place when first computing the economic feasibility of each alternative. Three additional sets of strategies were also analyzed for the alternatives as an evaluation of the sensitivity of the analysis to assumptions regarding local flood protection strategies (as discussed in Section 3.8).

For each trace analyzed, costs and benefits for the 50-year period of analysis starting on October 1, 2000 were brought back to present worth and then annualized using an interest rate of 6-3/8%. The benefits of the project include:

- Damages prevented by the project(s),
- Cost savings for postponed or avoided flood protection, and
- Reduction in upper basin storage costs.

These benefit categories are consistent with National Economic Development (NED) criteria. All values were computed using 2001 dollars. For alternatives that include an outlet, the outlet was assumed to be operational on May 1, 2005, and, therefore, capable of operating for the final 45.5 years of the 50-year period of analysis.

The net benefits and benefit-cost ratio (BCR) of each alternative were computed for comparison between alternatives. The BCR equals the benefits divided by the costs. A BCR greater than one indicates that benefits are greater than costs and an economically justifiable alternative. Net benefits equal the benefits described above, less the costs for construction and operation of the project(s). Note that high net benefits do not necessarily result in a high BCR; if the alternative also involves high costs, these will enlarge the denominator of the ratio and reduce the BCR. An alternative is considered to be economically justified if the net benefit is greater than zero; such alternatives will necessarily have a BCR greater than one.

The selected alternative is typically the alternative with the largest net benefit, although risk and effectiveness must also be considered.

The results of the stochastic and Wet Future Scenario analyses are described in Section 4.0 of this report. The results of the sensitivity analyses are described in Section 5.0 of this report.

3.8 Sensitivity Analysis – Local Flood Protection Strategies Adjacent to the Lake

Although the use of the set of *most likely actions* (Section 3.6.3) most closely approximates the NED prescription for economic analysis of the emergency outlet, other combinations of strategies were also examined in the analysis. This was done to determine how sensitive the results would be to the assumptions regarding local flood protection measures. Again, the with-project condition and without-project condition were compared while the local flood protection strategies were held constant.

The three other sets of local flood protection strategies that were analyzed as assumptions were:

- *Set of Cost-Effective Flood Protection Strategies*
  This set of strategies was selected based on the maximum net benefits (i.e., benefits minus costs) for each feature. The selection was made independent of previous protection measures. This required separate economic analysis of many different strategies for each feature. For the 24 features analyzed in this study, this included a total of 128 strategies. The most cost-effective flood protection strategy could be different for the with-project and the without-project conditions.

- *Set of Maximum Flood Protection Strategies (at the First Decision/Action Level)*
  This analysis assumed that at the first decision/action level, flood protection measures would be implemented to protect for any possible future lake level. For example, for a community, this strategy could require immediate construction of a levee to protect the town to the maximum possible flood level (elevation 1463). This assumption represents the extreme of efforts to protect local infrastructure.

  For each feature, the maximum protection strategy would provide flood protection to the maximum expected lake level (elevation 1463) at the first decision/action level. Therefore, no further flood protection measures would be necessary to protect the features. Where more than one maximum protection strategy could be considered for a particular feature, the strategy with the least cost was selected.

- *Set of No Protection Strategies*
  This analysis assumed that local flood protection measures would not be implemented regardless of the lake's level. This assumption represents the extreme of least effort to protect local infrastructure.

While these assumptions may not be realistic for some features, they help determine the sensitivity of the model results to the assumptions made regarding local flood protection actions. The following table lists all of the sets of feature protection strategies that were evaluated for this Economic Analysis.

Set of Strategies	Future
Most Likely Actions	Without project
	With project
Cost-Effective	Without project
	With project
Maximum Protection	Without project
	With project
No Protection	Without project
	With project

3.9 Sensitivity Analysis—Maximum Infrastructure Protection Adjacent to the Lake

In the Economics Analysis, it was generally assumed that the *most likely actions* with respect to local flood protection measures would be implemented—with or without a project. This set of *most likely actions* was assumed to be the without-project condition for most alternatives evaluated in this study, meeting the National Economic Development (NED) criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project." The sensitivity (of the economic results) to this assumption was also evaluated, however, through analysis of the alternatives that included the Maximum Infrastructure Protection approach.

Analysis of the alternatives that include Maximum Infrastructure Protection provides a comprehensive evaluation of flood protection measures within the basin. For these alternatives, the types of emergency measures that are currently being pursued in the basin were assumed to be part of the **project**—rather than assumed to be present in the without-project condition. Therefore, for these alternatives, the without-project condition assumes no flood protection for the features. The following table illustrates these feature protection assumptions compared to the conditions assumed for the other alternatives.

Assumptions Regarding Infrastructure Strategies

	Without Project	With Project
Alternatives That Do Not Include Maximum Infrastructure Protection	Most likely actions	Most likely actions
Alternatives That Include Maximum Infrastructure Protection	No flood protection	Most likely actions, along with Expanded Infrastructure Measures

Evaluation of these alternatives allows a determination of the economic feasibility of implementing the most likely action flood protection strategies for all of the features adjacent to the lake, assuming this is the comprehensive plan for flood protection at Devils Lake. These measures include: building levees, raising roads and rail lines, relocation of homes, etc., and altering the existing flood barriers to make them safer. They also include the Expanded Infrastructure Measures that take additional measures to ensure the safety of flood barriers in areas where roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake (described in Section 3.1). For this analysis, it is assumed that the measures would be undertaken incrementally—on a step-by-step basis, and only as needed. Construction of flood protection measures has previously been evaluated by local, state, and regional agencies on a feature-by-feature basis, because there is no comprehensive plan for local flood protection.

The project costs for the alternatives that include Maximum Infrastructure Protection take into account (at a minimum):

- The costs for implementation of flood protection measures for the features adjacent to the lake (including: building levees, raising roads and rail lines, relocation of homes, etc., and expanding the measures to ensure safe protection of all areas) and

- The costs for operation and maintenance for levees that protect communities and cities adjacent to the lake.

Two of the combination alternatives were also evaluted under this sensitivity analysis:

- Combination of the Upper Basin Management alternative with Maximum Infrastructure Protection. The alternative combines the currently used flood protection strategies with storage in the upper basin to better protect the primary features around the lake.

- Combination of the West Bay 300 cfs constrained outlet with Upper Basin Management and Maximum Infrastructure Protection. In addition to construction of an outlet that directs flow from the West Bay of Devils Lake into the Peterson Coulee, the alternative includes the currently used flood protection strategies and upper basin storage to protect the primary features around the lake.

3.10 Sensitivity Analysis—Moderate and Dry Future Scenarios

The stochastic analysis provides an average economic estimate based on the probability of future lake levels. Because the recent lake levels have exceeded the predictions that have been based on historical lake levels, the Wet Future Scenario analysis was also evaluated. However, it was necessary to also evaluate the economic feasibility of various alternatives based on average or dry scenarios to define the sensitivity under a wide range of potential futures.

This sensitivity analysis evaluated a set of three scenarios that are representative of three categories of future lake levels—a Dry Future and two Moderate Futures. These scenario analyses are representative of various categories within the stochastic traces, as noted.

Dry Future Scenario—The traces represented by this scenario generally show a decreasing pattern in the inflows and lake levels. The Dry Future represents those traces that have an average peak lake level of 1448 (approximately 36% of the stochastic traces). This dry future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Moderate Future 1 Scenario—Moderate Future 1 represents those traces that have an average peak lake level of 1450 (approximately 30% of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Moderate Future 2 Scenario—Moderate Future 2 represents those traces that have an average peak lake level of 1455 (approximately 25% of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

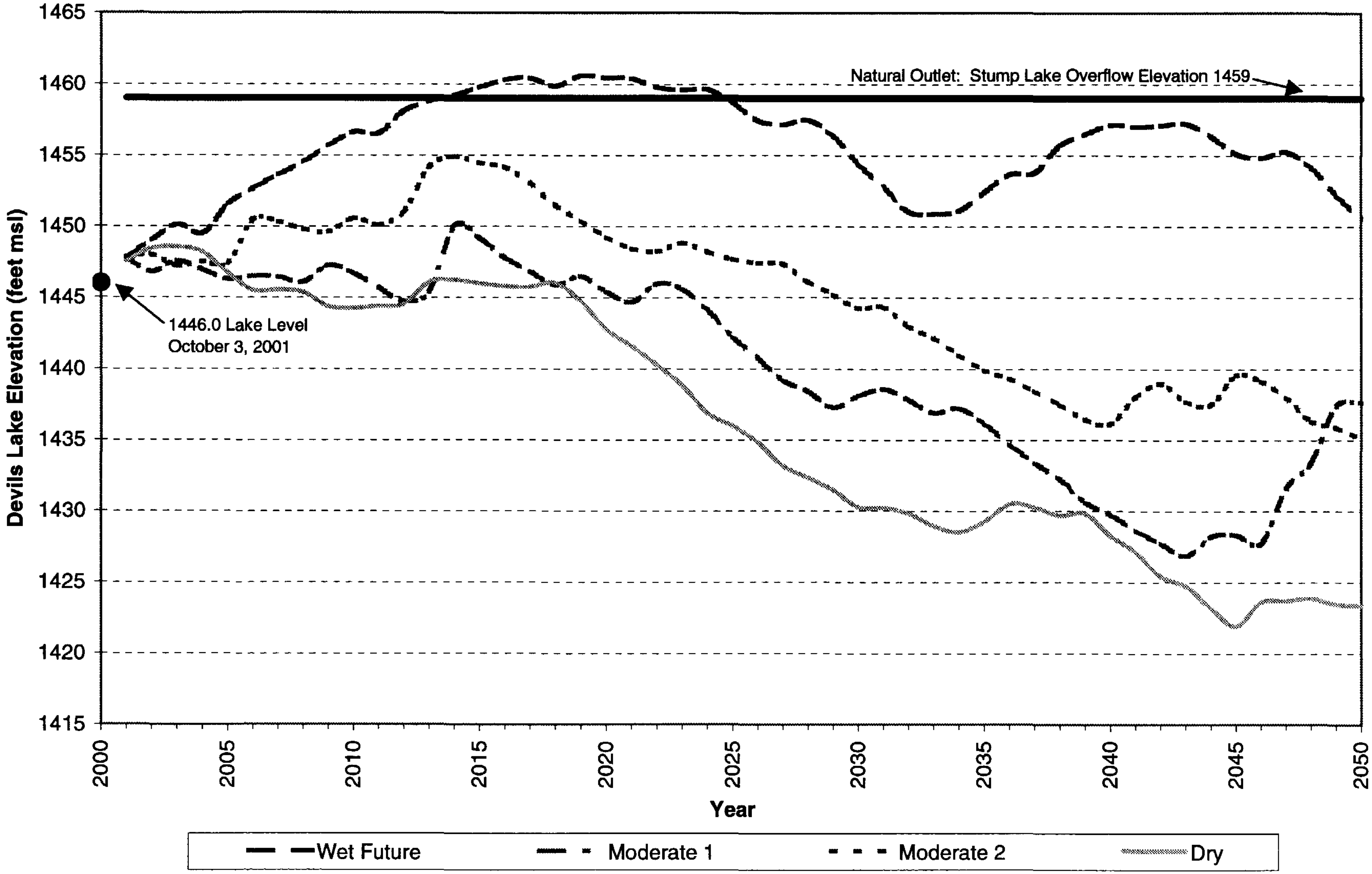
These three traces of future lake levels are plotted on Graph 2 for the without-project conditions. For purposes of comparison, Graph 2 also shows the Wet Future Scenario trace.   Although the exact weather conditions assumed for these futures will probably never occur, examination of these futures helps determine the sensitivity of the model results to the assumptions made regarding future climatic and hydrologic conditions.

3.11 Sensitivity Analysis—Erosion of the Natural Outlet

The analysis of alternatives assumed that there would be no erosion of the natural outlet or Tolna Coulee channel. This assumption was based on the conjecture that State or Federal agencies would protect the natural outlet at its current configuration in the case of a natural overflow. Because it is impossible to predict what may actually be implemented because of environmental, political, or social reasons, a sensitivity analysis of this assumption was necessary to define the degree of influence on the economic feasibility of the alternatives.

The erosion sensitivity analysis evaluates the impacts of erosion at the overflow point and adjacent upper reaches of Tolna Coulee. The coulee upper channel profile consists of two relatively steep sections located on both sides of a broad, flat marshy area that initially controls the outflow from Stump Lake. The upstream end of this marshy area is slightly higher than the initial Stump Lake overflow point. Erosion was assumed to start at the downstream end of this broad marshy area and proceed upstream to the overflow point. It was assumed that erosion would continue until the upper coulee becomes stable, a uniform slope having been achieved. Soil information at the natural outlet is limited but suggests the soils are moderate to highly erodible.

Wet, Moderate, and Dry Future Scenario Traces
Without Project Conditions



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Graph 2

Based on the most recent surveys, overflow from Stump Lake occurs when the lake level reaches an elevation of 1459.1 feet. The analysis indicates that the outlet control point would slowly be eroded, with the maximum potential erosion occurring down to 1450.8.

Using sediment transport rates and the volume of overflow, the time for this erosion to occur was estimated to be approximately nine months. The sediment transport rates and associated discharge rating curves were used in the USGS model to evaluate the impacts on the lake level and downstream channel characteristics.

Under this analysis, a peak discharge of 1440 cfs was expected to occur during year 17. (This compares to a peak discharge of only 206 cfs when no erosion of the Tolna Coulee is assumed.) With erosion at the outlet, the peak lake level is reduced by 0.17 feet, and the duration of high lake levels is much shorter. Graph 3 compares the lake levels for the Wet Future Scenario when erosion is and is not assumed. As shown by this graph, land adjacent to the lake will be relieved from flooding sooner if erosion occurs at the natural outlet. Therefore, landowners and farmers would be able to return to their land sooner.

3.12 Limitations on Use of Data

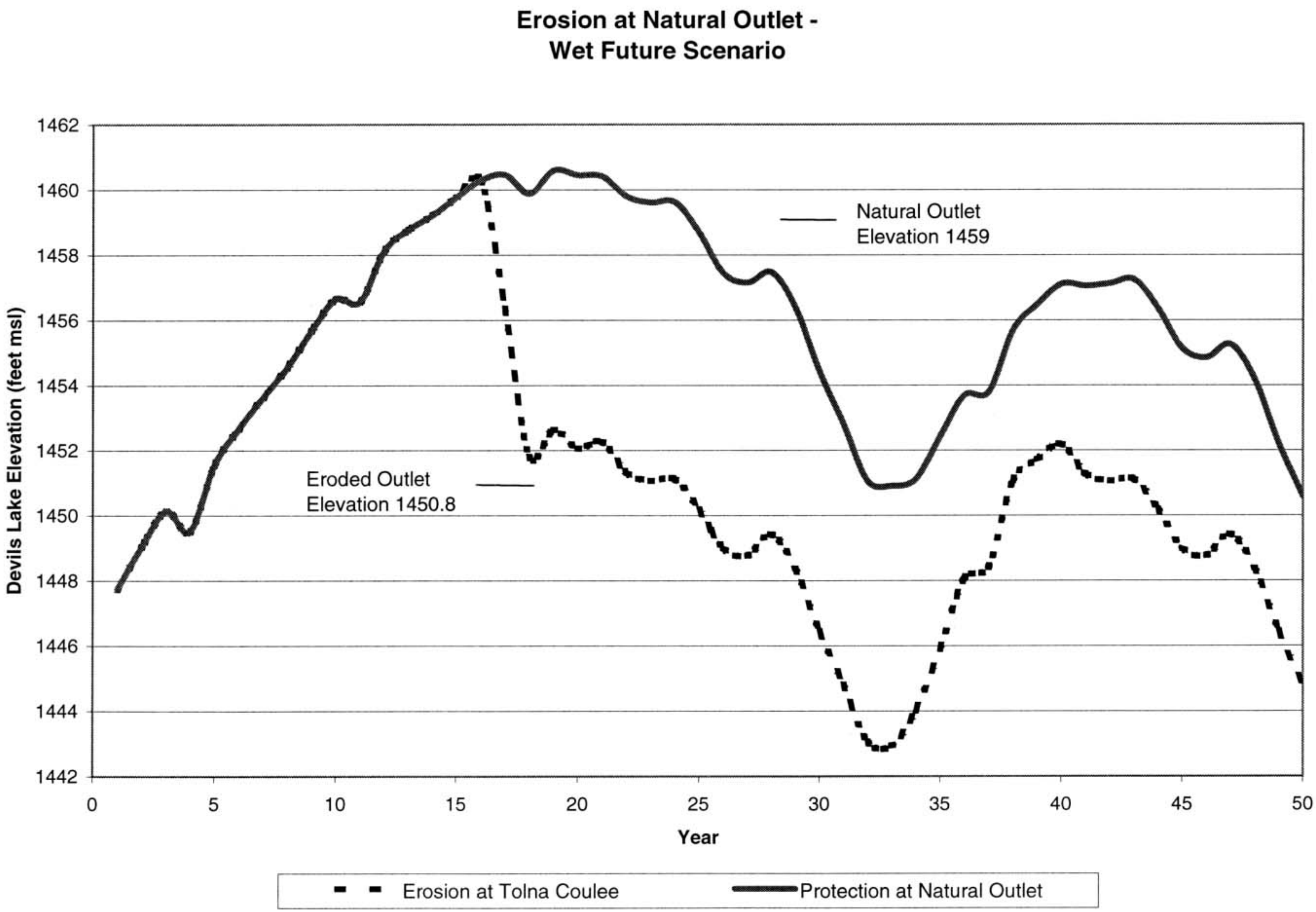
The Economic Analysis is meant to provide an evaluation of various emergency alternatives and the sensitivity of their economic feasibility to various flood responses in the region. The study also results in an assessment of:

- Protection measures that could be done for various features if the lake kept rising under without-project and with-project conditions.
- Potential damages to features adjacent to the lake and downstream of the lake along the Sheyenne River and the Red River of the North.

Taken as an overview across all the features around the lake, the Economic Analysis conclusions regarding overall strategies and costs for infrastructure protection and mitigation are probably reasonable.

It is important, however, that caution be exercised in the interpretation and use of Economic Analysis results. The Economic Analysis should not be used by decision-makers to assess plans for specific local features. When a decision regarding flood protection for a given feature is needed, the appropriate Federal, State, and local officials should conduct a more detailed, updated assessment to make sure they are selecting the best technically, economically, environmentally, and socially sound plan of action.

The Economic Analysis is based on a reconnaissance-level investigation of features, with limited regard for environmental, social, and local economic impacts both around the lake and along the downstream rivers. Regional impacts of residual damages or impacts from the set of no protection strategies were not considered.



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Graph 3

Decisions on implementing flood protection measures for individual features will ultimately depend on decisions by governmental units regarding priorities, budgets, cost-sharing provisions, regulations, etc., and on the local traffic patterns, land uses, and development trends at the time of the decision. The results of these decisions may have little resemblance to what was assumed for the Economic Analysis. Note, for example, that financial considerations are extremely important. The Economic Analysis did not evaluate overall affordability for any of the strategies that might be considered by local officials. Several questions relating to affordability of any alternatives include:

- Would Congress appropriate Federal funds for these projects?
- Would the NDDOT have enough funds to cover all the road raises?
- Would local sponsors have enough funds to cover the non-Federal share for levee raises?
- Could all actions really be taken, when estimated costs total over $1 billion?

Note also that the results of the Economic Analysis are all based on evaluations of the benefits of a project over a 50-year period. At the same time, it should be recognized that the Canadian Government might choose to allow outlet operation only for the current emergency situation; operation might only be allowed for a few years, until Devils Lake recedes and pumping can be discontinued. Resumption of pumping at some future date might require further coordination with the Canadian Government. In this case, the results of this Economic Analysis probably overstate the actual benefit of the outlet, considering that Canadian consent for outlet operation to reduce future episodes of high lake levels is not guaranteed. This overstatement is mitigated somewhat by the fact that the present worth of costs and benefits incurred in later years (when concurrence is not guaranteed) is much smaller than the present worth of costs and benefits received during early years of a project (when support is more likely).

4.0 Results of Stochastic and Wet Future Analyses

This section summarizes the results of the alternatives analysis using the set of most likely action strategies for protection of features adjacent to Devils Lake. These are the strategies that most closely conform to NED criteria for Federal economic evaluations. Economic analyses typically use the net benefits to compare alternatives. The alternative with the largest net benefit is selected, taking into account risk and effectiveness.

The results were evaluated under two different types of analyses:

- Stochastic Analysis—average results over all 10,000 traces. [In this stochastic analysis, some traces had results that were more than the average and some traces had results that were less than the average.]
- Wet Future Scenario Analysis—results based on the trace that repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993–1999) for three cycles and then assumes climatic and hydrologic conditions similar to 1980–1999.

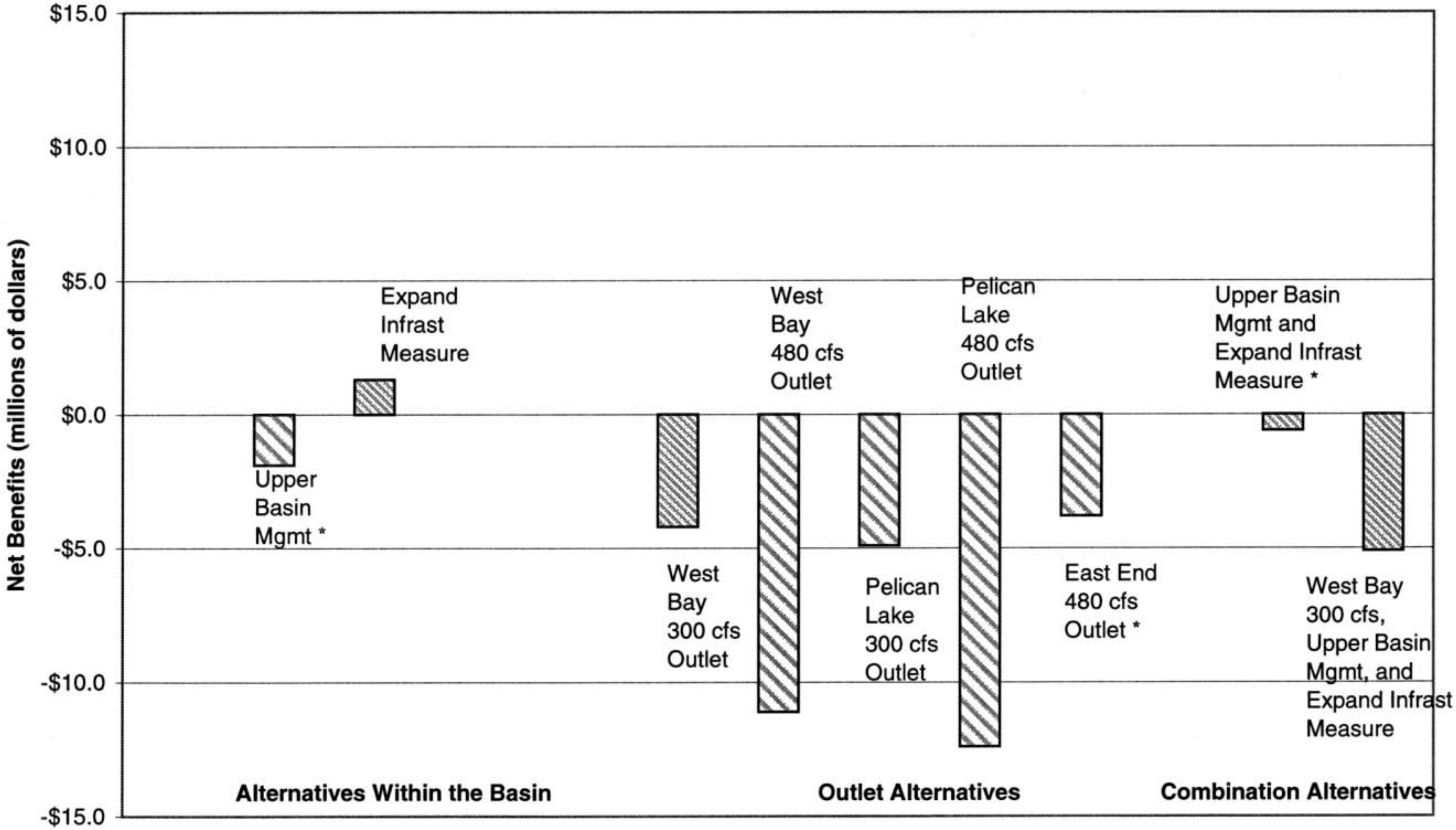
Further details regarding the costs and benefits that are provided by each alternative can be found in Part II of the Technical Appendix.

4.1 Stochastic Analysis Results

Graph 4 compares the net benefits of the alternatives under the stochastic analysis. Table 6 compares the detailed results of the alternatives under the stochastic analysis for the risk (project costs), effectiveness (reduction in damages and lake level), and economic results (net benefits and BCR).

In general, the benefits of the alternatives (when assuming the set of most likely action strategies) are primarily a function of costs avoided for delay or prevention of flood protection measures. The alternatives also reduce the average annual infrastructure damages and modify the downstream damages due to the changes in river flows and water quality. These downstream damages can result in positive or negative benefits, depending on the changes in flow rates and water quality in the downstream rivers during the natural overflows from Devils Lake.

Comparison of Net Benefits by Alternative for the Stochastic Analysis



* These stochastic results do not include the impact of downstream damages.

Table 6

Comparison of Stochastic Analysis Results (All dollar amounts in millions)

Analysis Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Adjacent to the Lake: Damages Prevented by Project (%)	Adjacent to the Lake: Costs Avoided by Project (%)	Highest Lake Level[6]	Downstream Damages Avoided[7] (%)	Annual Project Costs[2]	First Costs[3]	BCR
Alternatives within the Basin									
ST-1	Upper Basin Management	-$1.9 [4]	6%	7%	1458	NA	$2.7	$39.7	0.29 [5]
ST-2b	Expanded Infrastructure Measures	$1.3	0%	23%	1458	0%	$1.1	$15.2	2.10
Outlet Alternatives									
ST-3	West Bay 300 cfs Constrained Outlet	-$4.2	10%	13%	1456	1%	$5.8	$71.4	0.28
ST-4	West Bay 480 cfs Unconstrained Outlet	-$11.1	26%	29%	1453	-29%	$11.2	$146.7	0.01
ST-5	Pelican Lake 300 cfs Constrained Outlet	-$4.9	18%	24%	1455	1%	$7.8	$97.5	0.37
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	26%	32%	1453	-20%	$13.8	$182.7	0.10
ST-10	East End 480 cfs Unconstrained Outlet	-$3.8 [4]	26%	29%	1453	NA	$7.2	$47.7	0.88 [5]
Combination Alternatives									
ST-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	-$0.6 [4]	6%	29%	1458	NA	$3.7	$53.7	0.84 [5]
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	14%	38%	1456	1%	$9.4	$133.7	0.46

1 The net benefits listed include the downstream impacts, where available. Downstream impacts are not available for an alternative if the downstream costs and damages were not analyzed for the alternative. Alternatives where downstream impacts are not available are shown with a “4”.
2 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.
3 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs.
4 Net Benefits without downstream impacts considered. Actual net benefits would be expected to vary slightly from those shown.
5 Based on benefits without downstream impacts considered. Actual BCRs would be expected to vary slightly from those shown.
6 Based on the 10% probability lake level.
7 The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

4.1.1 Stochastic Analysis Results: Alternatives within the Basin

4.1.1.1 Upper Basin Management

The annualized total costs for the Upper Basin Management alternative are $2.7 million for construction of flood control structures, purchasing property easements, and removal of the flood control structures when the lake level recedes (for the 50-year planning period).

The Upper Basin Management alternative reduces the peak lake levels by only about 1 foot between the 100% and 10% probability levels.[10] This alternative does not negatively impact the downstream river concentrations, however, neither does it appreciably decrease the possibility of a natural overflow.

The combined annual benefits (the sum of the individual benefits) of this Upper Basin Management alternative are $0.8 million. Although this alternative will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible and was therefore not computed.

Using the set of most likely action strategies for the features adjacent to Devils Lake, the annual net benefit equals -$1.9 million, i.e., the average annual costs exceed the average annual benefits. The BCR is 0.29. Because the net benefits are negative, the Upper Basin Management alternative is not economically justified using the set of most likely action strategies under the stochastic analysis. Additional considerations for this alternative are the feasibility of upper basin storage implementation in prime farmland and the potential social and environmental impacts in the upstream basin.

4.1.1.2 Expanded Infrastructure Measures

The annualized costs for implementation of the Expanded Infrastructure Measures alternative total $1.1 million for the 50-year planning period.

The Expanded Infrastructure Measures alternative has no computed effect on the peak lake levels. Similarly, this alternative will not reduce the natural overflows from Devils Lake. Therefore this alternative has no downstream impacts.

The annual net benefit of this alternative using the set of most likely action strategies equals $1.3 million. The BCR is 2.10. Because the net benefits are positive, the Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies under the stochastic analysis.

4.1.1.3 Raise Natural Outlet

The Raise Natural Outlet was not evaluated under the stochastic analysis. This alternative is described in Section 4.2.1.3, under the Wet Future Scenario.

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10 The “probability level” is defined as the percent chance that the lake will reach a certain level, based on the climate assumptions and project(s).

4.1.2 Stochastic Analysis Results: Outlet Alternatives

4.1.2.1 West Bay Outlet

The total annualized costs for the West Bay 300 cfs constrained outlet alternative total $5.9 million for the 50-year planning period. The total annual costs for the West Bay 480 cfs unconstrained outlet are much larger, at $11.2 million for the 50-year planning period.

The West Bay 480 cfs unconstrained outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level. The West Bay 300 cfs constrained outlet has less effect, reducing the peak lake level by about 2 feet at the 10% probability level and by about 1 foot at the 50% probability level.

The 300 cfs constrained outlet reduces the average annual downstream damages and the 480 cfs unconstrained outlet increases the average annual downstream damages. The combined annual benefit (the sum of the individual benefits) of the West Bay 300 cfs constrained outlet is $1.6 million. The West Bay 480 cfs constrained outlet has a much smaller combined annual benefit of $0.1 million.

Using the set of most likely action strategies for local flood protection, the West Bay 300 cfs constrained outlet has an average net benefit of -$4.2 million, i.e., the average annual costs exceed the average annual benefits. The BCR is 0.28. The West Bay 480 cfs unconstrained outlet has significantly larger costs and much smaller benefits. The BCR is 0.01. Because the net benefits are negative, these West Bay Outlet alternatives are not economically justified using the set of most likely action strategies according to the stochastic analysis.

4.1.2.2 Pelican Lake Outlet

The total annual costs for the Pelican Lake 300 cfs constrained outlet alternative are $7.8 million and for the 480 cfs unconstrained outlet alternative are $13.8 million for the 50-year planning period.

The Pelican Lake 480 cfs unconstrained outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level. The Pelican Lake 300 cfs constrained outlet has slightly less effect, reducing the peak lake level by about 4 feet at the 10% probability level and by about 1 foot at the 50% probability level.

The 300 cfs constrained outlet reduces the average annual downstream damages and the 480 cfs unconstrained outlet increases the average annual downstream damages.

The combined annual benefits (the sum of the individual benefits) of the Pelican Lake 300 cfs constrained outlet are $2.9 million. The Pelican Lake 480 cfs unconstrained outlet has a much smaller combined annual benefit of $1.4 million.

Using the set of most likely action strategies for local flood protection, the Pelican Lake 300 cfs constrained outlet has an average net benefit of -$4.9 million, i.e., the average annual costs exceed the average annual benefits. The BCR is 0.37. The Pelican Lake 480 cfs unconstrained outlet has significantly larger costs and much smaller benefits, with an average net benefit of -$12.4 million. The

BCR is 0.10. The stochastic analysis of the outlet alternatives shows that the net benefits are negative, indicating that the outlet alternatives are not economically justified using the set of most likely action local protection strategies.

4.1.2.3 East End Outlet

The total annualized costs for the East End 480 cfs unconstrained outlet alternative are $7.2 million for the 50-year planning period. The outlet reduces the peak lake level almost 5 feet at the 10% probability level and about 2 feet at the 50% probability level. The reduction in the average annual downstream damages was not computed for this outlet. The combined annual benefits of the East End 480 cfs unconstrained outlet are $3.4 million.

Using the set of most likely action strategies for local flood protection, the net benefit equals -$3.8 million, i.e., the average annual costs exceed the average annual benefits. The BCR is 0.88. Because the net benefits are negative, the East End 480 cfs unconstrained outlet is not economically justified using the set of most likely action strategies under the stochastic analysis. Inclusion of downstream damages would likely decrease the net benefits and lower the BCR.

4.1.3 Stochastic Analysis Results: Combination Alternatives

4.1.3.1 Upper Basin Management and Expanded Infrastructure Measures

The annualized cost of the projects are $3.7 million for the 50-year planning period.

This combination alternative reduces the peak lake level by only about 1 foot between the 100% and 10% probability levels. Although this alternative will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible and was therefore not computed.

The combined annual benefits (the sum of the individual benefits) for this alternative are $3.2 million.

Using the set of most likely action strategies, the net benefits are $-0.6 million. The BCR is 0.84. The average annual costs exceed the average annual benefits, therefore the combination Upper Basin Management and Expanded Infrastructure Measures alternative is not economically justified using the set of most likely action strategies. The addition of Upper Basin Management to the Expanded Infrastructure Measures alternative reduces the BCR from 2.10 to 0.29.

4.1.3.2 West Bay Outlet with Upper Basin Management and Expanded Infrastructure Measures

The annualized cost of the projects is $9.5 million for the 50-year planning period.

This combination alternative reduces the peak lake level about 3 feet at the 10% probability level and about 1 foot at the 50% probability level.

The average annual downstream damages are reduced by this alternative. The combined annual net benefits of this alternative (using the set of most likely action strategies) equal $5.1 million. The BCR is 0.46. The average annual benefits exceed the average annual costs, therefore the combination West Bay

300 cfs constrained outlet,[11] Upper Basin Management, and Expanded Infrastructure Measures alternative is not economically justified using the set of most likely action strategies.

4.1.4 Comparison of Stochastic Results

4.1.4.1 Alternatives within the Basin

The Expanded Infrastructure Measures alternative has the largest net benefits of the alternatives within the basin, and the only alternative with a positive net benefit. The project for this alternative is the Expanded Infrastructure Measures to ensure safe protection of the area (raise roads as levees and build perimeter dikes). There is minimal financial risk with this alternative because the incremental protection measures are completed as required and the project costs are spread over a several-year duration. A limitation of this alternative is that the protection area is limited to the area within the levee system. There is no assurance that features outside of this levee system will be protected from the rising lake levels.

The Upper Basin Management alternative prevents more damages than the other alternatives within the basin. However the net benefits are less than zero, indicating it is not economically justified.

The Raise the Natural Outlet alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level. It was not evaluated under the stochastic analysis. However, a supposition regarding economic feasibility can be made based on the results of the Wet Future scenario analysis and a comparison of the sensitivity to the stochastic analysis. Since the annual net benefits under the Wet Future analysis are relatively small, it is likely that construction of the Raise the Natural Outlet alternative would not be economically feasible at this time. The likelihood of the lake levels reaching the overflow are fairly small for the stochastic analysis, and construction of this alternative may become economically feasible if the overflow becomes more likely.

4.1.4.2 Outlet Alternatives

The study evaluated the economic feasibility of three outlet locations: East End, West Bay, and Pelican Lake. The East End 480 cfs unconstrained gravity outlet has the largest annual net benefit of the outlet alternatives, although the net benefits are negative. (It should also be noted that the calculated net benefits do not effect of downstream impacts—effects that would likely lower the net benefits even further.) The negative net benefit signifies that this alternative is technically just below the cutoff of being economically justified (net benefits must be positive). This outlet is also the most effective outlet at reducing the lake levels. Although the East End Outlet may provide the largest net benefit, there is an associated risk with this outlet: the potential impacts to the downstream rivers may great, due to the relatively poor water quality in the East Bay of Devils Lake. Therefore, the East End Outlet may not be a cost-effective alternative.

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11 Had other outlets (e.g., Pelican Lake, East Bay) been substituted, it is likely that the economic indices for other-outlet combination alternatives would vary in accord with the relationship of those indices for the various outlets when not in combination.

The West Bay and Pelican Lake 300 cfs constrained outlets have similar annual negative net benefits. The project costs are also high, indicating a high financial risk for investment of Federal funds. Although these outlets are not economically justified under the stochastic analysis, they may have fewer risks to the downstream rivers than the East End outlet since the water that is released is constrained by downstream water quality and quantity standards.

The West Bay and Pelican Lake 480 cfs unconstrained outlets have the lowest annual negative net benefits. The project costs are also very high, indicating an even higher financial risk for investment of Federal funds. These unconstrained outlets are not economically justified under the stochastic analysis. They also have relatively higher risks to the downstream rivers than the 300 cfs constrained outlets since the water that is released is not constrained by downstream water quality and quantity standards.

Some local agencies and residents may perceive the outlet alternatives as providing the greatest degree of protection to relieve the pressures of the prolonged flooding problems.

4.1.4.3 Combination Alternatives

Combinations of three projects (West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures) were analyzed to determine if combining projects would increase net benefits. The combinations include both Upper Basin Management and Expanded Infrastructure Measures, one with a West Bay outlet and the other without.

These combination alternatives have a negative annual net benefit. The negative net benefits signify that these combination alternatives are not economically justified under the stochastic analysis. Because the Expanded Infrastructure Measures alternative is the only alternative with a BCR greater than one, the addition of other projects (for example, one of the outlets) makes the BCR smaller, and makes the resulting combination alternative economically infeasible. In addition, the potential impacts to the downstream rivers would be greater with the outlet combination.

4.2 Wet Future Scenario Analysis

Graph 5 compares the net benefits of the alternatives under the Wet Future Scenario analysis. Table 7 compares the detailed results of the alternatives under the Wet Future Scenario analysis for the risk (project costs), effectiveness (reduction in damages and lake level), and economic results (net benefits and BCR).

Under this Wet Future Scenario, all of the alternatives that were analyzed result in a positive net benefit, which indicates that all of the alternatives would be economically feasible.

Comparison of Net Benefits by Alternative for the Wet Future Scenario

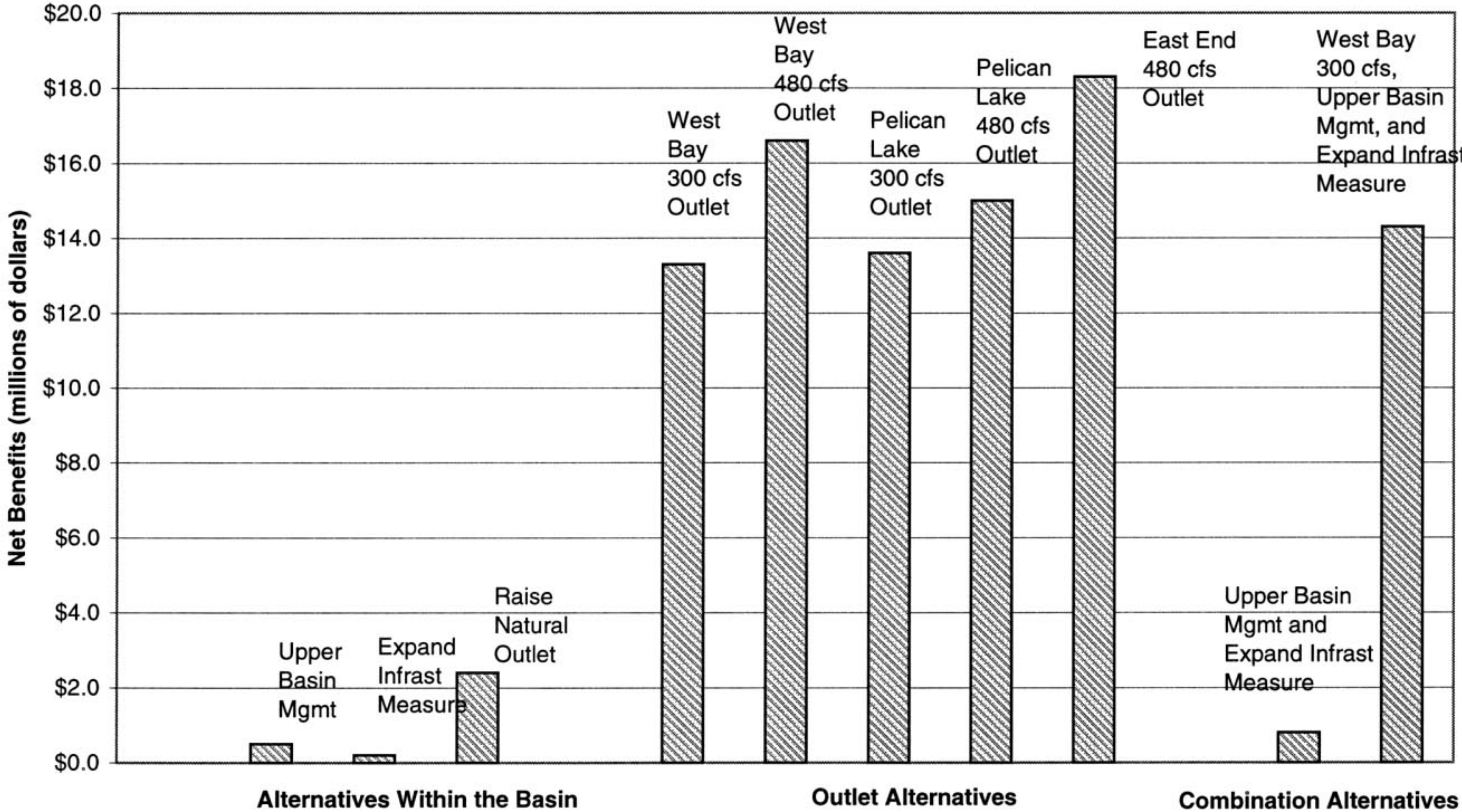


Table 7

Comparison of Wet Future Scenario Analysis Results
(all dollar amounts in millions)

Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts	Adjacent to the Lake: Damages Prevented by Project (%)	Adjacent to the Lake: Costs Avoided by Project (%)	Highest Lake Level	Downstream Damages Avoided[4] (%)	Annual Project Costs[1]	First Costs[2]	BCR
Alternatives within the Basin									
WF-1	Upper Basin Management	$0.5	5%	6%	1460	4%	$2.7	$39.7	1.20
WF-2b	Expanded Infrastructure Measures	$0.2	0%	11%	1460	0%	$4.1	$54.8	1.06
WF-11	Raise Natural Outlet	$2.4	0%	0%	1462	22%[3]	$1.1	$15.9	3.24
Outlet Alternatives									
WF-3	West Bay 300 cfs Constrained Outlet	$13.3	32%	39%	1457	19%	$6.4	$71.4	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$16.6	56%	70%	1452	-6%	$12.2	$148.2	2.37
WF-5	Pelican Lake 300 cfs Constrained Outlet	$13.6	33%	45%	1457	19%	$8.3	$97.7	2.62
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$15.5	56%	70%	1452	2%	$14.7	$183.0	2.06
WF-10	East End 480 cfs Unconstrained Outlet	$18.3	56%	70%	1452	-10%	$9.9	$137.8	2.85
Combination Alternatives									
WF-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	$0.8	6%	16%	1460	4%	$6.5	$91.4	1.13
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$14.3	35%	54%	1456	19%	$11.2	$139.4	2.28

1 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.
2 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs.
3 Downstream damages would theoretically be reduced by 100% for this alternative. However, this computation of damages avoided includes remaining flow-related damages that are due to local precipitation events.
4 The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

4.2.1 Wet Future Scenario Analysis Results: Alternatives within the Basin

4.2.1.1 Upper Basin Management

The annualized total costs for the Upper Basin Management alternative are $2.7 million for construction of flood control structures, purchasing property easements, and modification of the flood control structures when the lake level recedes (for the 50-year planning period).

The Upper Basin Management alternative reduces the peak lake level by less than 0.2 feet under the Wet Future Scenario. This reduction in lake levels results in a 4% reduction of the downstream river damages under the Wet Future Scenario.

The combined annual benefits (the sum of the individual benefits) of this Upper Basin Management alternative are $3.2 million.

Using the set of most likely action strategies for the features adjacent to Devils Lake, the annual net benefit equals $0.5 million, i.e., the annual benefits exceed the annual costs. The BCR is 1.20. Because the net benefits are positive, the Upper Basin Management alternative is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis. Additional considerations for this alternative are the feasibility of upper basin storage implementation in prime farmland and the potential social and environmental impacts in the upstream basin.

4.2.1.2 Expanded Infrastructure Measures

The annualized costs for implementation of the Expanded Infrastructure Measures alternative total $4.1 million for the 50-year planning period under the Wet Future Scenario.

The Expanded Infrastructure Measures alternative has no computed effect on the peak lake levels. Similarly, this alternative will not reduce the natural overflows from Devils Lake. Therefore this alternative has no downstream impacts.

The annual net benefit of this alternative using the set of most likely action strategies equals $0.2 million. The BCR is 1.06. Because the net benefits are positive, the Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

4.2.1.3 Raise Natural Outlet

The annualized costs for implementation of the Raise Natural Outlet alternative total $1.1 million for the 50-year planning period under the Wet Future Scenario. The actual costs of this alternative may differ from those predicted by this analysis if different assumptions are made in estimating compensation for induced damages.

The Raise Natural Outlet alternative raises the Wet Future Scenario peak lake levels by 2.2 feet as a result of installation of the permanent weir. The downstream impacts, however, are reduced by 22% under the Wet Future Scenario.

The annual net benefit of this alternative (using the set of most likely action strategies) equals $2.4 million. The BCR is 3.24. In addition, the net benefits are positive, so the Raise the Natural Outlet alternative is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

4.2.2 Wet Future Scenario Analysis Results: Outlet Alternatives

4.2.2.1 West Bay Outlet

The total annualized costs for the West Bay 300 cfs constrained outlet alternative total $6.4 million for the 50-year planning period. The total annual costs for the West Bay 480 cfs unconstrained outlet are much larger, at $12.2 million for the 50-year planning period.

The West Bay 480 cfs unconstrained outlet reduces the Wet Future Scenario peak lake level by 7.7 feet. The West Bay 300 cfs constrained outlet has less effect, reducing the peak lake level by about 2.9 feet.

The 300 cfs constrained outlet reduces the annual downstream damages and the 480 cfs unconstrained outlet increases the annual downstream damages. The combined annual benefit (the sum of the individual benefits) of the West Bay 300 cfs constrained outlet is $19.7 million. The West Bay 480 cfs unconstrained outlet has a much larger combined annual benefit of $28.8 million.

Using the set of most likely action strategies for local flood protection, the West Bay 300 cfs constrained outlet has a net benefit of $13.3 million, i.e., the annual benefits exceed the annual costs. The BCR is 3.09. The West Bay 480 cfs unconstrained outlet has significantly larger costs, but also larger net benefits ($16.6 million). The BCR is 2.37. Because the net benefits are positive, these West Bay Outlet alternatives are both economically justified using the set of most likely action strategies according to the Wet Future Scenario analysis. The 480 cfs unconstrained outlet has larger net benefits.

4.2.2.2 Pelican Lake Outlet

The total annual costs for the Pelican Lake 300 cfs constrained outlet alternative are $8.3 million and for the 480 cfs unconstrained outlet alternative are $14.7 million for the 50-year planning period.

The Pelican Lake 480 cfs unconstrained outlet reduces the peak lake level 7.7 feet under the Wet Future Scenario. The Pelican Lake 300 cfs constrained outlet has slightly less effect, reducing the peak lake level by about 3.2 feet.

Both the 300 cfs constrained and the 480 cfs unconstrained outlets reduce the annual downstream damages.

The combined annual benefits (the sum of the individual benefits) of the Pelican Lake 300 cfs constrained outlet are $21.9 million. The Pelican Lake 480 cfs constrained outlet has a much larger combined annual benefit of $30.2 million.

Using the set of most likely action strategies for local flood protection, the Pelican Lake 300 cfs constrained outlet has a net benefit of $13.6 million, i.e., the annual benefits exceed the annual costs. The

BCR is 2.62. The Pelican Lake 480 cfs unconstrained outlet has significantly larger costs and larger benefits, with a net benefit of $15.5 million. The BCR is 2.06. Because the net benefits are positive, the outlet alternatives are economically justified using the set of most likely action local protection strategies according to the Wet Future Scenario analysis. The 480 cfs unconstrained outlet has larger net benefits.

4.2.2.3 East End Outlet

The total annualized costs for the East End 480 cfs unconstrained outlet alternative are $9.9 million for the 50-year planning period. The outlet reduces the peak lake level 7.7 feet under the Wet Future Scenario. The outlet increases the downstream damages by 10%. The combined annual benefits of the East End 480 cfs unconstrained outlet are $28.2 million.

Using the set of most likely action strategies for local flood protection, the net benefits equal $18.3 million, i.e., the annual benefits exceed the annual costs. The BCR is 2.85. Because the net benefits are positive, the East End 480 cfs unconstrained outlet is economically justified using the set of most likely action strategies under the Wet Future Scenario analysis.

4.2.3 Wet Future Scenario Analysis Results: Combination Alternatives

4.2.3.1 Upper Basin Management and Expanded Infrastructure Measures

The annualized costs of the projects are $6.5 million for the 50-year planning period.

This combination alternative reduces the peak lake level by less than 0.2 feet under the Wet Future Scenario. The damages to downstream features are reduced by about 4% under this alternative using the Wet Future Scenario.

The combined annual benefits (the sum of the individual benefits) for this alternative are $7.3 million.

Using the set of most likely action strategies, the net benefits are $0.8 million. The BCR is 1.13. Therefore, the combination Upper Basin Management and Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies.

4.2.3.2 West Bay Outlet with Upper Basin Management and Expanded Infrastructure Measures

The annualized costs of the project are $11.2 million for the 50-year planning period.

This combination alternative reduces the peak lake level by 4.1 feet under the Wet Future Scenario.

The average annual downstream damages are reduced by 19% under this alternative. The combined annual net benefits of this alternative (using the set of most likely action strategies) equals $14.3 million. The BCR is 2.28. The annual benefits exceed the annual costs, therefore the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures alternative is economically justified using the set of most likely action strategies.

4.2.4 Comparison of Wet Future Scenario Results

As noted earlier, under the Wet Future Scenario, all of the alternatives show a positive net benefit. This means that all of the alternatives would be economically feasible, and the alternative with the largest net benefit would typically be selected. However, risks and effectiveness must also be considered when evaluating the alternatives.

The Wet Future Scenario results in general indicate much larger net benefits than the stochastic analysis. It is apparent that if the climatic conditions persist in the same manner as in the highest recent years, implementation of any of the alternatives is economically justified.

4.2.4.1 Alternatives within the Basin

The Raise the Natural Outlet alternative has the largest net benefits of the alternatives within the basin. This alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level. However, the annual net benefits may not accurately represent the costs for induced damages around the lake (which could be highly variable).

The Expanded Infrastructure Measures alternative ensures safe protection of the area (raise roads as levees and build perimeter dikes). There is little financial risk with this alternative because the incremental protection measures are completed as required and the project costs are spread over a several-year duration. A limitation of this alternative is that the protection area is restricted to the area within the levee system. There is no assurance that features outside of this levee system will be protected from the rising lake levels.

The Upper Basin Management alternative prevents more damages and avoids more costs than the other alternatives within the basin.

4.2.4.2 Outlet Alternatives

Under the Wet Future Scenario, the outlet alternatives have the largest net benefits of the alternatives analyzed. The 480 cfs unconstrained outlets are the most effective at reducing the lake levels, which is critical for this Wet Future Scenario. However, the project costs are also very high for these outlets, indicating a high financial risk for investment of Federal funds.

The East End 480 cfs unconstrained gravity outlet has the largest annual net benefits. Despite having the largest net benefits, however, the potential impacts to the downstream rivers may be much worse than predicted because the water quality in the East End of Devils Lake is relatively poor. Therefore, the East End Outlet may not be a cost-effective alternative.

The West Bay and Pelican Lake 480 cfs unconstrained outlets have annual net benefits similar to the East End 480 cfs unconstrained outlet. These unconstrained outlets also have relatively higher risks to the downstream rivers than the 300 cfs constrained outlets since the water that is released is not constrained by downstream water quality and quantity standards.

The West Bay and Pelican Lake 300 cfs constrained outlets have slightly lower annual net benefits than the 480 cfs unconstrained outlets, although they are still very high. The project costs are lower than the 480 cfs unconstrained outlets, indicating a lower financial risk for investment of Federal funds. These outlets may also have fewer risks to the downstream rivers than the East End outlet since the water that is released is constrained by downstream water quality and quantity standards.

Some local agencies and residents may perceive the outlet alternatives as providing the greatest degree of protection to relieve the pressures of the prolonged flooding problems.

4.2.4.3 Combination Alternatives

The combinations include both Upper Basin Management and Expanded Infrastructure Measures, one with a West Bay 300 cfs constrained outlet and the other without. The combination alternative with the outlet (Combination 2) has a larger annual net benefit than the one without the outlet (Combination 1). Combination 2 also has net benefits that are larger than the 300 cfs constrained outlet alternatives. However, the project costs are also larger for this combination, indicating a higher financial risk for investment of Federal funds. Combination 2 also reduces the potential impacts to the downstream rivers.

Note that not all outlet possibilities were examined for this Economic Analysis; it is possible that other outlets could provide larger net benefits.

5.0 Results of Sensitivity Analysis

Questions regarding the sensitivity of the economic analysis (as described in Chapter 4) to its basic assumptions led to an investigation of the effects using other potential assumptions. The intention of these investigations was to determine whether the analysis was sensitive to assumptions regarding:

1. The flood protection strategies for features adjacent to Devils Lake
2. The without-project condition with respect to the degree of flood protection for features adjacent to the lake (most likely actions, or no flood protection)
3. The future climatic and hydrologic conditions (moderate or dry future analyses)
4. The configuration of the natural outlet

Although these sensitivity analyses may not precisely conform to NED criteria for Federal economic evaluations, they provide a range that demonstrates the economic analyses' sensitivity to the critical assumptions and the potential effect of these assumptions on the net benefits.

5.1 Assumptions Regarding Local Flood Protection Strategies Adjacent to the Lake

For the purposes of determining Federal interest in the proposed alternatives to protect the Devils Lake basin, the set of most likely action strategies most closely represents the NED valuation of flood damages in this analysis. While the set of most likely action strategies most closely represents the NED computation of damages, it is by no means a perfect measure. Some possible weaknesses in the computations follow:

- Action 'trigger' levels for features adjacent to Devils Lake may be at too high an elevation (1 foot below the design level of protection), so that quick rises in lake level could overwhelm emergency actions resulting in more damages than this analysis would indicate.
- Institutions responsible for the emergency actions (FEMA, DOT) may not use the criteria developed in this analysis to make their decisions.
- Limits on available resources or funds may delay or prohibit intended emergency actions.

As described above in Section 3.8, three other sets of strategies were analyzed for most of the alternatives to determine whether the assumptions regarding local flood protection strategies adjacent to Devils Lake would significantly affect the outcome of the economic analysis. These were the set of cost-effective strategies, the set of maximum protection strategies, and the set of no protection strategies. Aside from the selection of strategies, the procedures were identical to the analysis of the set of most likely action strategies.

5.1.1 Overall Effect

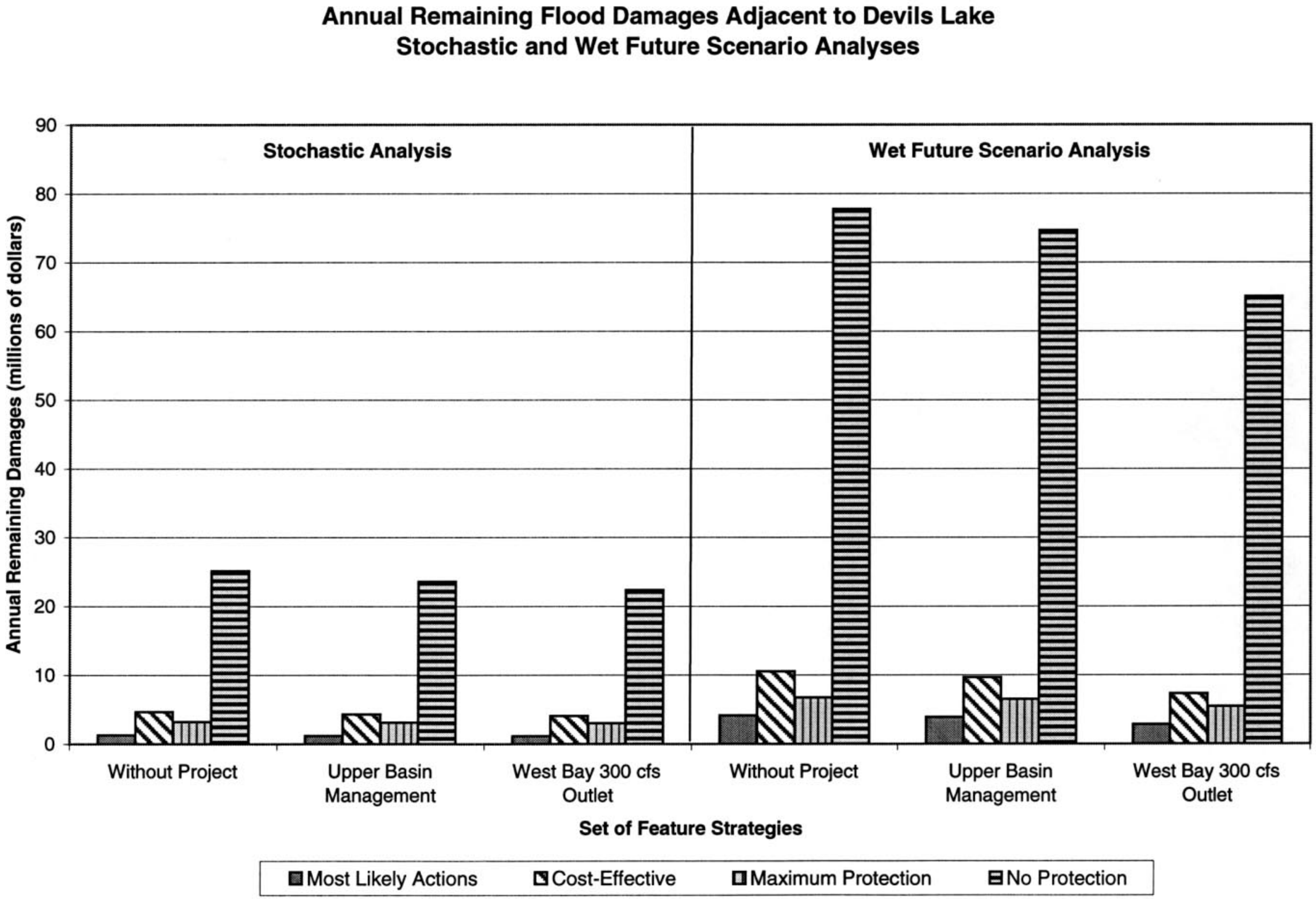
A total of three sets of local flood protection strategies were examined in this sensitivity analysis: cost-effective, no protection, and maximum protection at the first action level. To illustrate the typical effect of each of these sets of strategies, the annual benefits were compared to the benefits under the most likely action strategy for two of the alternatives. The comparisons of these benefits for other alternatives may differ slightly, however, the general conclusions remain the same. The only exception to this pattern concerns the Expanded Infrastructure Measures alternatives (discussed below).

Graph 6 illustrates the remaining annual flood damages (infrastructure damages not prevented) without and with the project for the four sets of strategies, under both the stochastic and Wet Future Scenario analyses. The damages for these two project alternatives are also compared to the "without-project" damages. Clearly the assumptions regarding local flood protection measures have a significant impact on the remaining damages in the basin.

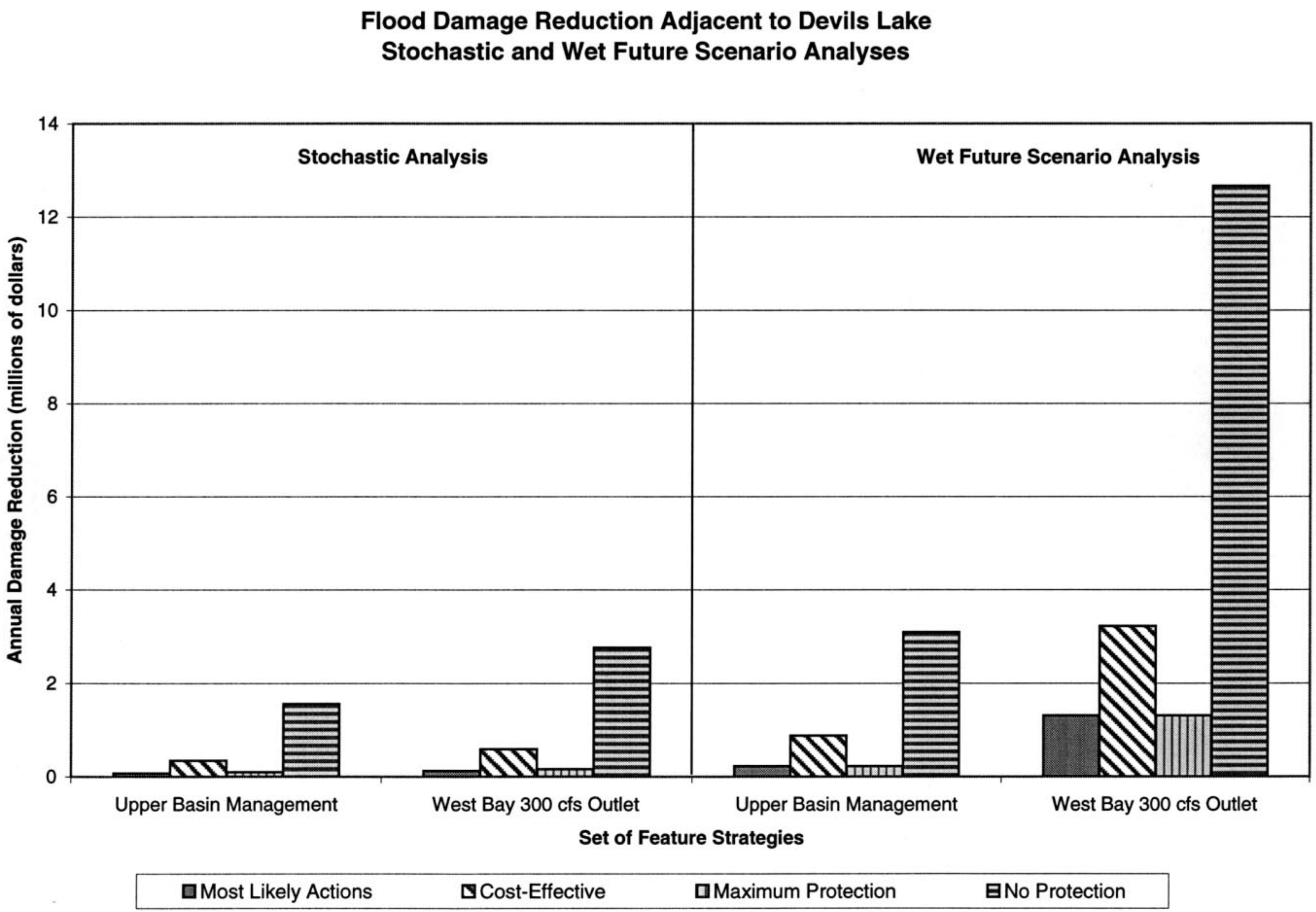
Graph 7 illustrates the flood damage reduction for the four sets of strategies under the two alternatives, using both the stochastic and Wet Future Scenario analyses. This graph shows that the assumptions regarding local flood protection measures also significantly affect the potential flood damage reduction of the alternatives. The set of most likely action strategies appears to provide the smallest reduction of flood damages. However, the benefit of each alternative is also dependent on the cost savings for the flood protection measures (not included in this graph).

Graph 8 illustrates the combined flood damage reduction and cost savings (benefits) that are provided by these two alternatives, under both the stochastic and Wet Future Scenario analyses. This graph indicates that, except for the set of no protection strategies, the sets of strategies appear to have similar effects on the combined damage reduction and cost savings. Among these sets of strategies (except the no protection strategy), the set of most likely action strategies can provide the most benefits to the alternatives.

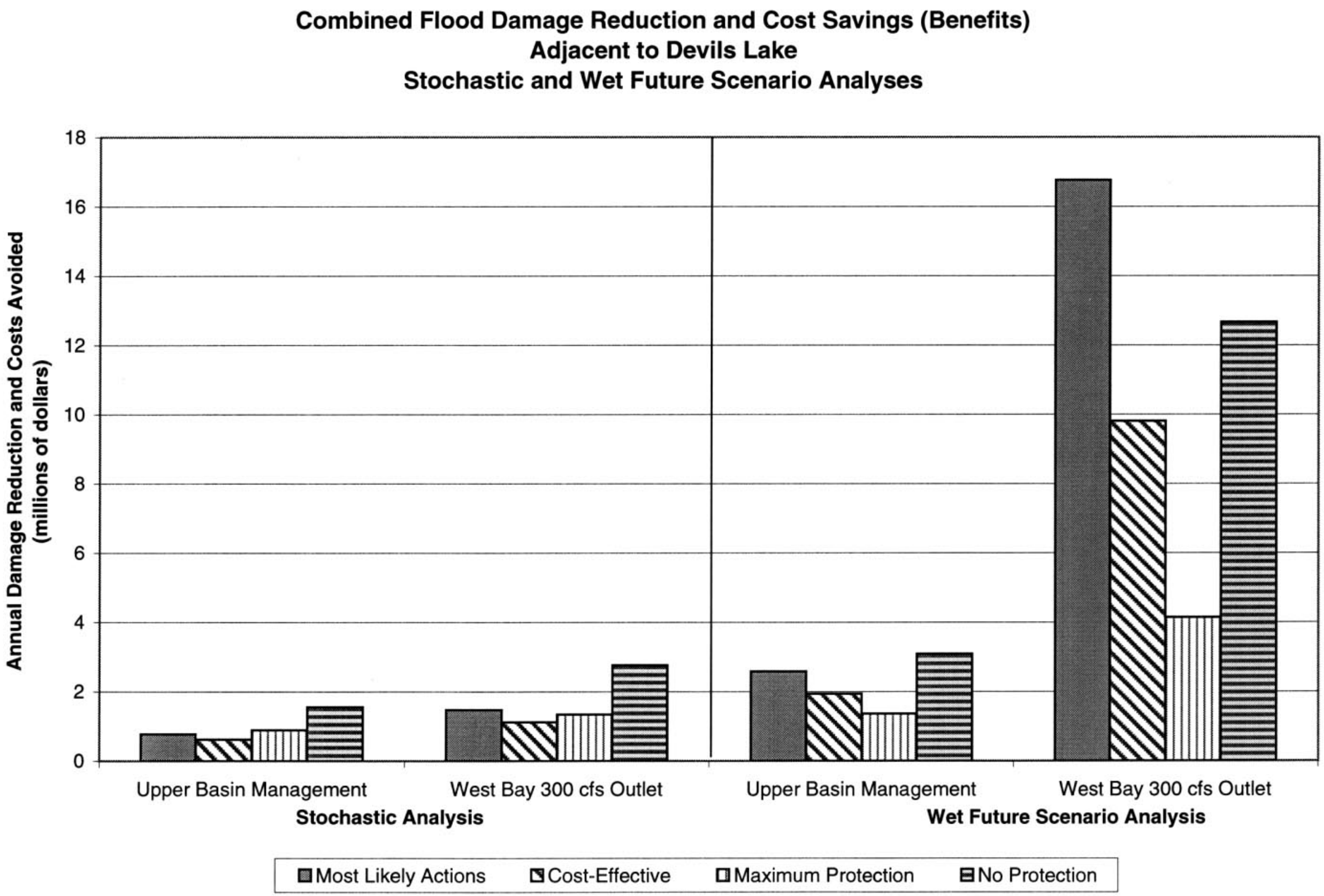
The Expanded Infrastructure Measures alternatives do not follow the patterns described above and shown in Graphs 6 through 8. The project benefits for this alternative are the reduction in the number of roads to be raised (because the perimeter dams protect the roads) and the protection of homes within the protected area. Therefore, the analysis of this alternative involves comparing the value of the perimeter dams and levees (with-project conditions) versus raising the roads (without-project conditions)—two different methods of protecting features in the same area. All other alternatives assume the same set of protection strategies for with-project and without-project conditions. Therefore, the conclusions regarding the Expanded Infrastructure Measures do not follow the same pattern as discussed above.


Annual Remaining Flood Damages Adjacent to Devils Lake
Stochastic and Wet Future Scenario Analyses
Stochastic Analysis
Wet Future Scenario Analysis
Annual Remaining Damages (millions of dollars)
0
10
20
30
40
50
60
70
80
90
Without Project
Upper Basin Management
West Bay 300 cfs Outlet
Without Project
Upper Basin Management
West Bay 300 cfs Outlet
Set of Feature Strategies
Most Likely Actions
Cost-Effective
Maximum Protection
No Protection

Graph 6


Flood Damage Reduction Adjacent to Devils Lake
Stochastic and Wet Future Scenario Analyses
Stochastic Analysis
Wet Future Scenario Analysis
Annual Damage Reduction (millions of dollars)
0
2
4
6
8
10
12
14
Upper Basin Management
West Bay 300 cfs Outlet
Upper Basin Management
West Bay 300 cfs Outlet
Set of Feature Strategies
Most Likely Actions
Cost-Effective
Maximum Protection
No Protection

Graph 7



Combined Flood Damage Reduction and Cost Savings (Benefits)
Adjacent to Devils Lake
Stochastic and Wet Future Scenario Analyses
Annual Damage Reduction and Costs Avoided
(millions of dollars)
0
2
4
6
8
10
12
14
16
18
Upper Basin Management
West Bay 300 cfs Outlet
Stochastic Analysis
Upper Basin Management
West Bay 300 cfs Outlet
Wet Future Scenario Analysis
Most Likely Actions
Cost-Effective
Maximum Protection
No Protection

Graph 8

5.1.2 Set of Cost-Effective Strategies

The strategy that provides the largest net benefit for each feature was selected for this set of strategies. The benefits of the alternative are the reduction in damages and a reduction in protection costs.

In general, the set of cost-effective strategies provide approximately the same benefits as the set of most likely action strategies. This is expected, because the feature protection measures for the two sets of strategies are the same for many of the features. For example, U.S. Highway 2 is raised incrementally under both sets of strategies. This is true for many of the features. Because future actions regarding flood protection measures may vary depending on many parameters, either of these sets of strategies could likely occur in the basin.

5.1.3 Set of Maximum Protection Strategies

This set of strategies assumed implementation of flood protection measures that will protect to the lake's expected maximum level, regardless of the cost of these projects. Under these assumptions, the alternative's primary effect would be an immediate and ultimate protection.

Although the set of maximum protection strategies at the first action level could provide similar benefits as the sets of most likely action strategies, the maximum protection strategy is not likely to be implemented for any or all features. These large benefits require very large investments in local flood protection at a fairly low lake level. If the project can avoid or delay these expenditures, it may produce slightly larger benefits than if a smaller expenditure (i.e., a more cost-effective strategy) would have been planned. However, it could be extremely difficult to find the funding required for implementation of the maximum protection strategies.

5.1.4 Set of No Flood Protection Strategies

There are no strategy costs for this set of strategies, and therefore the only benefits of the alternative are the reduction in damages.

The set of no flood protection strategies almost always provides the largest project benefit among the set of feature protection strategies. This is because the set of no protection strategies represents the minimum level of local flood protection effort. Therefore, the alternatives can prevent the most benefits (because nothing else is protecting the features around the lake). However, without the project, it appears that this set of strategies is unlikely to be implemented. Recent experience shows that local officials will likely locate funds for some flood protection projects and that these will probably be carefully selected to maximize damage reduction.

For the set of Expanded Infrastructure Measures alternatives, the set of no flood protection strategies provides minimal benefits. The only benefit is the protection of several homes and land. Although some of the road features would be protected with the project, the damages to roads are not reduced because all other roads in the basin are not protected (the raised sections connect to other roads that are not raised). Therefore, this alternative using no protection strategies is not a realistic solution to flooding in the basin.

5.2 Maximum Infrastructure Protection Adjacent to the Lake

The assumptions made regarding the set of most likely action strategies for feature protection have some possible weaknesses, as described in Section 5.1. In addition, one might call into question the assumption that identical sets of feature protection strategies would be implemented under both the without- and with-project conditions. To address these concerns, the Maximum Infrastructure Protection sensitivity analysis evaluates alternatives that assume a comprehensive plan would be in place to guarantee the construction of these Maximum Infrastructure Protection measures.

Table 8 compares the detailed results of the alternatives that include the Maximum Infrastructure Protection approach under the stochastic and the Wet Future Scenario analyses. Results are given in terms of risk (project costs), effectiveness (reduction in damages and lake level), and economic results (net benefits and BCR).

Table 8

Maximum Infrastructure Protection Analysis Results (all dollar amounts in millions)

Analysis Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Adjacent to the Lake		Highest Lake Level[6]	Downstream Damages Avoided[7] (%)	Annual Project Costs[2]	First Costs[3]	BCR
			Damages Prevented by Project (%)	Costs Avoided by Project (%)					
Stochastic Analysis									
ST-2a	Maximum Infrastructure Protection	$14.6	95%	0%	1458	0%	$9.3	$136.7	2.57
ST-7a	Combination 1 - Upper Basin Management and Maximum Infrastructure Protection	$12.7 [4]	95%	0%	1458	NA	$11.2	$165.6	2.14 [5]
ST-8a	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$8.2	96%	0%	1456	1%	$15.9	$221.3	1.52
Wet Future Scenario Analysis									
WF-2a	Maximum Infrastructure Protection	$34.5	95%	0%	1460	0%	$39.1	$579.5	1.88
WF-7a	Combination 1 - Upper Basin Management and Maximum Infrastructure Protection	$35.1	95%	0%	1460	4%	$39.4	$589.2	1.89
WF-8a	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$48.6	97%	0%	1456	19%	$29.4	$412.6	2.65

1 The net benefits listed include the downstream impacts, where available. Downstream impacts are not available for an alternative if the downstream costs and damages were not analyzed for the alternative. Alternatives where downstream impacts are not available are shown with a "4".
2 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.
3 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs. The first costs include the costs for implementation of the most likely action strategies to protect features that are adjacent to Devils Lake. These costs would not necessarily be incurred at the start of the 50-year future, but would be incurred as the lake level rises.
4 Net Benefits without downstream impacts considered. Actual net benefits would be expected to vary slightly from those shown.
5 Based on benefits without downstream impacts considered. Actual BCRs would be expected to vary slightly from those shown.
6 Based on the 10% probability lake level.
7 The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.

5.2.1 Results

5.2.1.1 Maximum Infrastructure Protection Results

Maximum Infrastructure Protection alone shows no effect on the peak lake levels. Similarly, this approach will not reduce or prevent any natural overflows from Devils Lake. Therefore, this approach has no downstream impacts.

The benefits of Maximum Infrastructure Protection are the reductions in infrastructure damages, which are decreased by 95% as a result of the flood protection measures (under both the stochastic and Wet Future Scenario analyses).

The annual net benefits of this approach to flood management are positive, indicating that the Maximum Infrastructure Protection measures are economically justified under both the stochastic and Wet Future Scenario analyses.

5.2.1.2 Upper Basin Management and Maximum Infrastructure Protection

This combination reduces the peak lake level by less than 1 foot on average. Although this will reduce the natural overflows from Devils Lake, the associated prevention of damages to downstream features was expected to be negligible under the stochastic analysis and was therefore not computed. Under the Wet Future Scenario analysis, the downstream damages are reduced by 4%.

The benefits of this combination also include the annual reductions in infrastructure damages, which are decreased by 95% as a result of the flood protection measures (under both the stochastic and Wet Future Scenario analyses).

The annual net benefits of this combination are positive, indicating that the combination Upper Basin Management and Maximum Infrastructure Protection alternative is economically justified under both the stochastic and Wet Future Scenario analyses. Examination of the results of the stochastic analysis shows, however, that the Maximum Infrastructure Protection alternative is better off without the addition of Upper Basin Management. The BCR for the Maximum Infrastructure Protection alternative becomes smaller when Upper Basin Management is added.

5.2.1.3 West Bay Outlet with Upper Basin Management and Maximum Infrastructure Protection

This combination reduces the peak lake level about 3 feet at the 10% probability level and about 1 foot at the 50% probability level under the stochastic analysis and by 4.1 feet under the Wet Future Scenario.

Benefits include the average annual reductions in infrastructure damages (at about 96% to 97%) and the reduction of downstream damages (1% under the stochastic analysis and 19% under the Wet Future Scenario analysis).

The combined annual benefits of this combination are positive. Because the net benefits are positive, the combination West Bay 300 cfs constrained outlet, Upper Basin Management, and Maximum Infrastructure Protection alternative is economically justified under the stochastic analysis.

5.2.2 Comparison of Results

The Maximum Infrastructure Protection sensitivity analysis indicates that all of the alternatives that include Maximum Infrastructure Protection provide positive annual net benefits. When Maximum Infrastructure Protection alone is considered, the net benefits are larger than those of any other alternative. This is true both for the stochastic and the Wet Future Scenario analysis. The implementation of the Maximum Infrastructure Protection measures within the basin is therefore economically justified.

Combining Maximum Infrastructure Protection measures with other projects within the basin provides a larger net benefit under the Wet Future Scenario. This implies that the wetter the future, the more that multiple types of projects are required in the basin to relieve the flooding. By contrast, under the more moderate climate assumptions of the stochastic analysis, adding other projects to Maximum Infrastructure Protection results in a reduction of net benefits, suggesting that such additions are economically infeasible.

There is little financial risk with the maximum infrastructure measures: the incremental protection measures are completed as required and the total project costs are spread over a several-year duration.

A shortcoming of implementing the Maximum Infrastructure Protection measures alone is that the measures do nothing to relieve the prolonged flooding problems while the wet period continues. This condition can be expected to be stressful for local agencies and residents.

5.3 Moderate and Dry Future Scenarios

5.3.1 Overall Effect

This sensitivity analysis evaluated three scenarios that are representative of categories of average or dry future lake levels—a Dry Future and two different Moderate Futures. The Moderate Future 2 peak lake level was 1455; Moderate Future 1 peak lake level was 1450; Dry Future Lake level was 1448. These future lake levels alter the damages prevented and the cost savings of each alternative, and therefore affect the net benefits. In general, the wetter the future, the more damages that can be prevented and costs that can be saved by the alternatives. In futures where a natural overflow to the Sheyenne River occurs, the alternatives can be credited with additional benefits due to reductions in the downstream impacts during the wetter futures (by reducing the duration of the overflow, or by preventing it altogether). No overflow occurs during these moderate and dry futures (without a project).

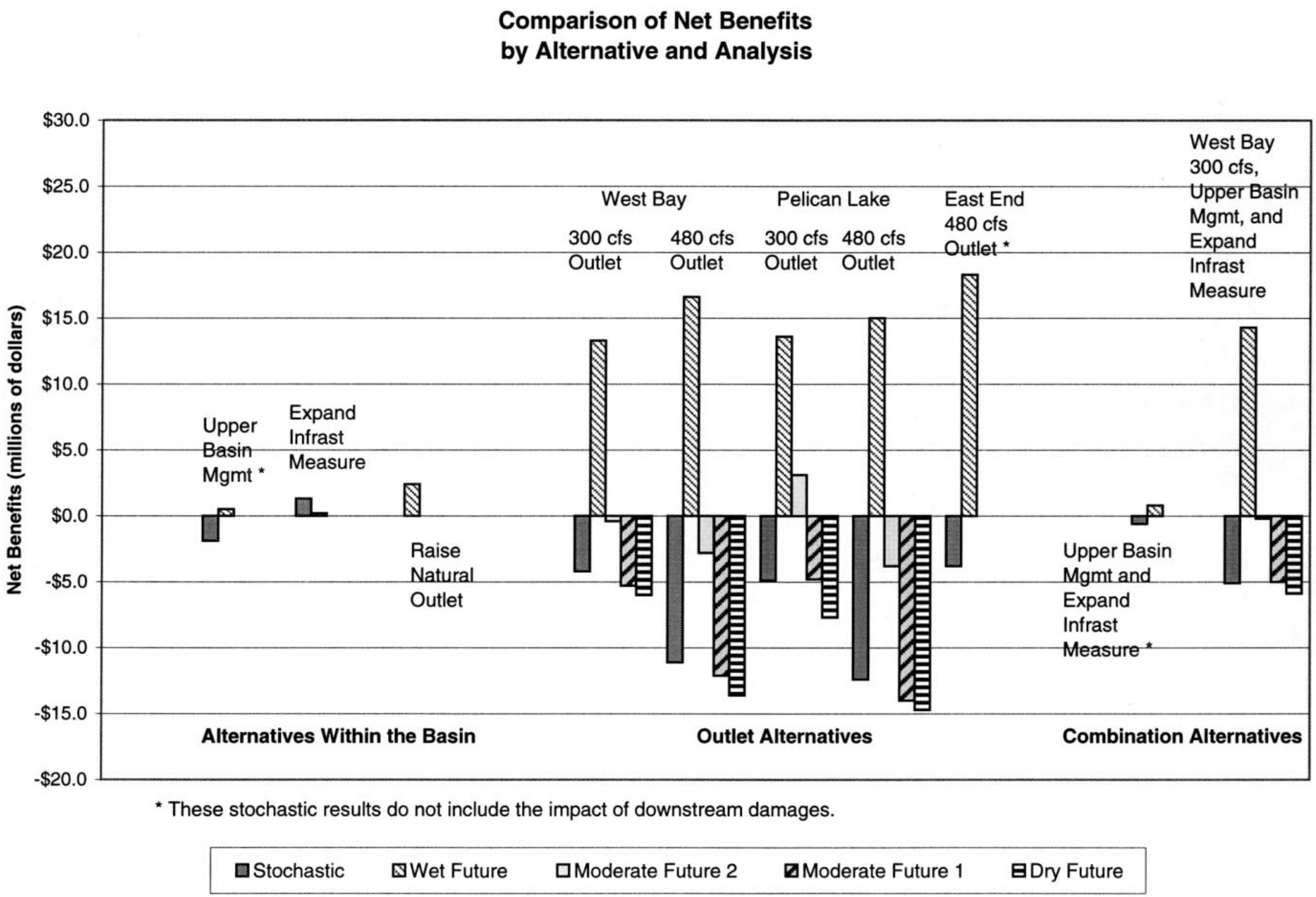
Therefore, the Moderate 2 Future results indicate larger net benefits for the alternatives than the Moderate 1 Future or Dry Future results. The Moderate Future 1 results (peak lake level of 1450) are similar to the results computed under the stochastic analysis. This is understandable, because the average and median peak lake levels are similar to the average stochastic levels. The future lake level traces used for the sensitivity analyses were shown on Graph 2 in Section 3.10.

The evaluation of the various alternatives under the stochastic and scenario analyses was very time consuming. Since this project is being completed in an expedited time frame, it was necessary to limit the analyses that were conducted. Therefore, analyses were limited to those necessary to draw conclusions regarding selection of the project(s) that provide the largest net benefits.

Graph 9 compares the net benefits of the alternatives under the stochastic and the four future scenario analyses. Table 9 on the following page provides a ranking of the alternatives under the moderate and dry scenario analyses. Data in Table 9 include the net benefits, the percent of damages prevented adjacent to the lake, the percent of costs avoided by the outlet, the peak lake level, the downstream damages avoided for each alternative, annual project costs, first costs, and BCR.

All of the alternatives have negative net benefits under the Moderate Future 1 and Dry Future scenarios. The only positive net benefit for the Moderate Future 2 scenario is for the Pelican Lake 300 cfs constrained outlet alternative.

It is interesting to note that the ranking of the alternatives changes, depending on the scenario that is used for the analysis. Therefore, the selection of the alternative is very sensitive to the assumptions regarding the future climate condition.


Comparison of Net Benefits
by Alternative and Analysis
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$0.0
-$5.0
-$10.0
-$15.0
-$20.0
Net Benefits (millions of dollars)
Upper Basin Mgmt *
Expand Infrast Measure
Raise Natural Outlet
West Bay
300 cfs Outlet
480 cfs Outlet
Pelican Lake
300 cfs Outlet
480 cfs Outlet
East End 480 cfs Outlet *
Upper Basin Mgmt and Expand Infrast Measure *
West Bay 300 cfs, Upper Basin Mgmt, and Expand Infrast Measure
Alternatives Within the Basin
Outlet Alternatives
Combination Alternatives
* These stochastic results do not include the impact of downstream damages.
Stochastic
Wet Future
Moderate Future 2
Moderate Future 1
Dry Future

Economic Analysis of Devils Lake Alternatives
Table 9

Comparison of Moderate and Dry Scenarios Results
(costs and benefits in millions of dollars)

Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Damages Prevented by Project[2] (Percent)	Costs Avoided by Project[2] (Percent)	Highest Lake Level	Downstream Damages Avoided[4] (Percent)	Annual Project Costs	First Costs[3]	BCR
Moderate Future 2 Scenario (1455 Peak)									
M2-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$20.2	96%	0%	1452	-1%	$18.4	$232.2	2.10
M2-5	Pelican Lake 300 cfs Constrained Outlet	$3.1	40%	59%	1450	-1%	$8.0	$97.1	1.38
M2-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$0.2	30%	54%	1452	-1%	$10.2	$133.2	0.98
M2-1	West Bay 300 cfs Constrained Outlet	-$0.4	14%	30%	1453	-1%	$5.9	$71.4	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	-$2.8	52%	69%	1448	-44%	$11.7	$148.8	0.76
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	-$3.8	52%	71%	1448	-31%	$14.4	$186.0	0.73
Moderate Future 1 Scenario (1450 Peak)									
M1-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$10.4	97%	0%	1448	-1%	$10.8	$146.2	1.96
M1-5	Pelican Lake 300 cfs Constrained Outlet	-$4.8	61%	45%	1447	-1%	$7.8	$97.1	0.38
M1-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.0	24%	59%	1448	-1%	$8.5	$111.1	0.41
M1-1	West Bay 300 cfs Constrained Outlet	-$5.3	22%	8%	1450	-1%	$5.8	$71.4	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	-$12.1	61%	45%	1447	-26%	$11.4	$149.1	-0.06
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.0	61%	45%	1447	-22%	$13.8	$183.0	-0.01
Dry Future Scenario									
DR-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$1.7	97%	0%	1448	-2%	$11.9	$162.9	1.15
DR-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.9	64%	38%	1448	-2%	$8.4	$111.1	0.30
DR-1	West Bay 300 cfs Constrained Outlet	-$6.0	0%	0%	1448	-3%	$5.8	$71.4	-0.04
DR-5	Pelican Lake 300 cfs Constrained Outlet	-$7.7	0%	6%	1448	-3%	$7.7	$97.1	0.01
DR-2	West Bay 480 cfs Unconstrained Outlet	-$13.6	0%	0%	1448	-33%	$10.8	$142.8	-0.26
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.7	0%	6%	1448	-19%	$13.4	$179.4	-0.10

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Where percentages are shown for "Damages Prevented" and "Costs Avoided", percentages are always based upon the damages or costs that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with å

[2]These damages prevented and costs avoided pertain only to the features adjacent to Devils Lake

[3]First costs do not include operation and maintenance costs. Natural Resources Mitigation and alternative water treatment are included in first costs.

[4]The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the damage category.

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5.3.2 Moderate Future 2 Scenario: 1455 Peak Lake Level

This Moderate Future 2 trace is one of the 10,000 stochastic traces, and serves as a representative of approximately 25% of those traces. It rises to a peak level of 1455 at about year 2014 and then recedes for the remaining 50 years.

The Moderate Future 2 results show net benefits that are slightly larger than those computed using the stochastic analysis. This could be anticipated, because the average peak lake level for the stochastic analysis was 1451.7 and the median was 1450.1. Because this trace has a higher peak lake level than the average stochastic trace, it results in larger net benefits because there are more damages to reduce. However, only one of the six alternatives had positive net benefits and a BCR greater than one—the Pelican Lake 300 cfs constrained outlet. Note that only some of the alternatives were analyzed for this dry future. It is possible that other alternatives would show a larger net benefit.

5.3.3 Moderate Future 1 Scenario: 1450 Peak Lake Level

This Moderate Future 1 trace is one of the 10,000 stochastic traces, and serves as a representative of approximately 30% of those traces. It rises to a peak level of 1450 at about year 2014 and then recedes for the remaining 50 years. It also has a second peak near the end of the 50-year period, but the maximum lake level during the second peak is much lower than the first peak.

The Moderate Future 1 results provide net benefits that are nearly the same as those computed using the stochastic analysis. This is reasonable, because the average peak lake level for the stochastic analysis was 1451.7 and the median was 1450.1 (the same as the peak lake level for this moderate future). None of the alternatives shows a positive net benefit. Note that only some of the alternatives were analyzed for this dry future. It is possible that other alternatives would show a larger net benefit.

5.3.4 Dry Future Scenario: 1448 Peak Lake Level

The Dry Future trace is also one of the 10,000 stochastic traces, and serves as a representative of approximately 36% of those traces. It rises to a peak level of about 1448 during the first couple of years and then recedes for the remaining 50 years. It also has several small peaks throughout the 50-year period, but the maximum lake level of these peaks is lower than the first peak.

The net benefits computed using the Dry Future scenario are lower than those computed using the stochastic analysis. This is reasonable, because there are fewer damages to prevent because the lake level basically declines both with and without the project. Again, none of the alternatives shows a positive net benefit. Note that only some of the alternatives were analyzed for this dry future. It is possible that other alternatives would show a larger net benefit.

5.4 Erosion of the Natural Outlet

Local interests have questioned the assumption that there would be no erosion of the natural outlet or Tolna Coulee channel. This sensitivity analysis addressed that concern by analyzing several of the alternatives under the assumption that the natural outlet does erode, and that no measures are constructed to protect the existing outlet configuration. Table 10 compares the results of the erosion analyses to the analyses that assume no erosion of the natural outlet. The results indicate that if erosion is considered, the net benefits of the alternatives are larger.

The sensitivity analysis results indicate that the erosion of the natural outlet does not significantly change the economic results for the features adjacent to the lake. This is to be expected, because the modeling shows that the peak lake levels are only 0.17 feet lower than they would be if no erosion is assumed.

However, the analysis does show that lands adjacent to the lake would be relieved of flooding sooner if erosion occurs. A somewhat intangible benefit of this, and one that is not accounted for in the Economic Analysis, is that property owners would be able to return to their lands sooner. Conversely, if the natural outlet is prevented from eroding, access by property owners would be restricted for longer periods.

Downstream damages, however, increase significantly when erosion of the natural outlet occurs during overflows. If it were assumed, therefore, that there was no erosion protection in place at the outlet, alternatives that prevent an overflow would show higher net benefits. These alternatives would prevent the higher downstream damages. This suggests that the net benefits of all the alternatives that prevent an overflow may have been somewhat underrated in this Economic Analysis. The without-project condition was always assumed to include erosion protection at the natural outlet, so the benefits of preventing erosion (by preventing an overflow) were hidden.

The primary increase in damages due to erosion is flow-related in urban areas during the year that the overflow takes place (increasing by more than $4 million). The industrial water treatment and the urban flow-related damages increase by nearly 50%, municipal water treatment damages increase by about 8%, and other flow-related damages increase by 5% to 10%. The increase in damages occurs primarily during the first three years that the overflow takes place. By contrast, irrigation-related damages are decreased by nearly 60%. This decrease in damages is a result of fewer years of irrigated crop damage. The downstream impacts are compared by category in Graph 10.

It should also be noted that the erosion of the natural outlet without project analysis does not include the additional damages that would occur due to the displacement and transport of the eroded material (approximately 937,000 cubic yards). This eroded material may cause additional physical and environmental damages in the downstream channel (in addition to those damages tabulated in this analysis). Including those additional damages in the analysis would increase the net benefits of the alternatives.

Table 10

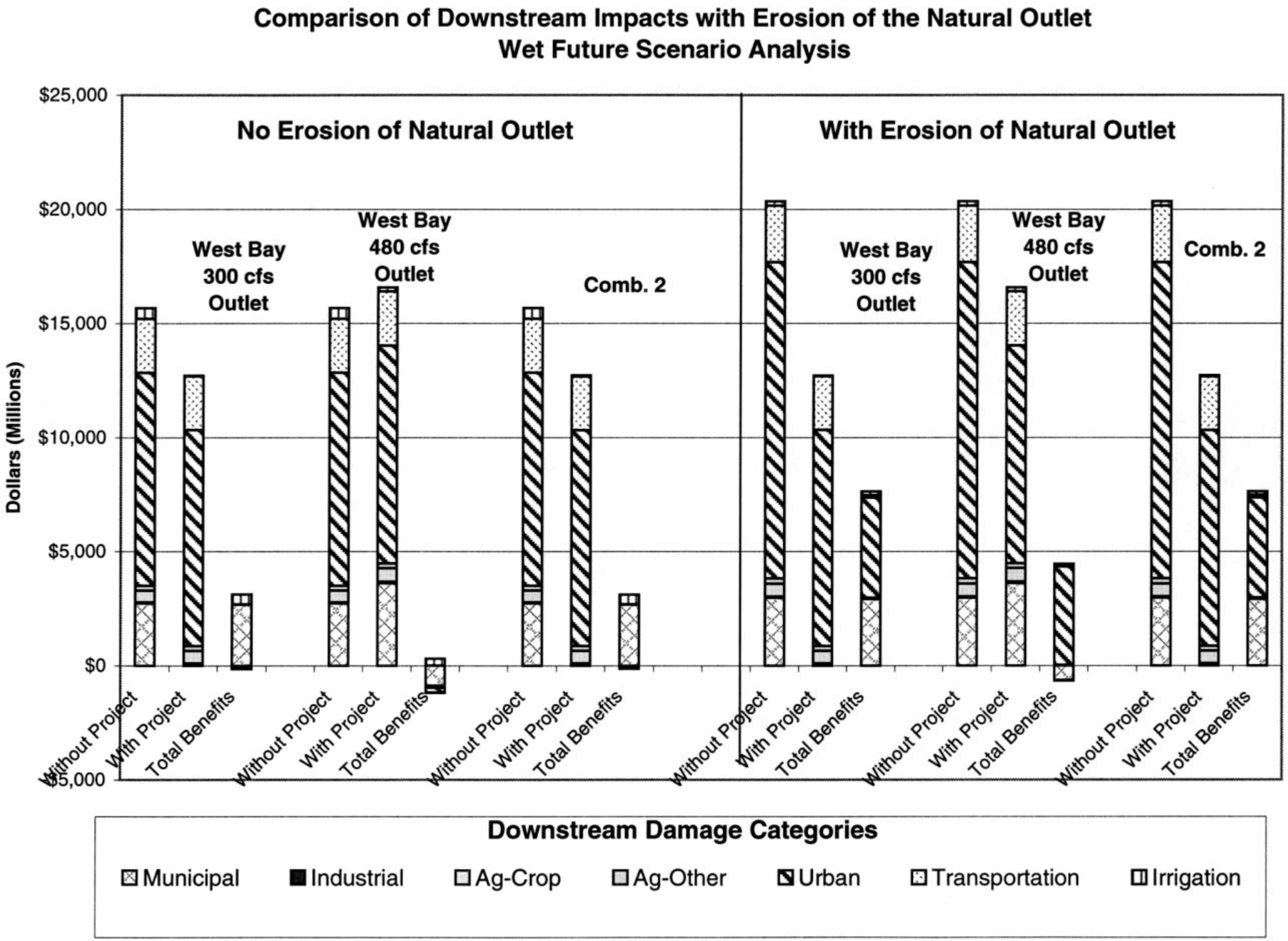
Erosion of the Natural Outlet Analysis Results
Wet Future Scenario Analysis
(all dollar amounts in millions)

Analysis Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Adjacent to the Lake: Damages Prevented by Project (%)	Adjacent to the Lake: Costs Avoided by Project (%)	Highest Lake Level	Downstream Damages Avoided[3] (%)	Annual Project Costs	First Costs[2]	BCR
No Erosion of Natural Outlet									
WF-3	West Bay 300 cfs Constrained Outlet	$13.3	32%	39%	1457	19%	$6.4	$71.4	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$16.6	56%	70%	1452	-6%	$12.2	$148.2	2.37
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$14.3	35%	54%	1456	19%	$11.2	$139.4	2.28
Erosion of the Natural Outlet									
WF-12	Natural Outlet Erosion: West Bay 300 cfs Constrained Outlet	$18.0	32%	39%	1457	38%	$6.4	$71.4	3.83
WF-13	Natural Outlet Erosion: West Bay 480 cfs Unconstrained Outlet	$21.3	56%	70%	1452	19%	$12.2	$148.2	2.75
WF-14b	Natural Outlet Erosion: Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$19.0	35%	54%	1456	37%	$11.2	$139.4	2.70

1 Annual project costs include all project costs (annualized) plus annual operation, maintenance, and monitoring costs.

2 First costs include outlet construction costs, upper basin storage implementation, natural resources mitigation, and alternative water treatment costs. The first costs include the costs for implementation of the most likely action strategies to protect features that are adjacent to Devils Lake. These costs would not necessarily be incurred at the start of the 50-year future, but would be incurred as the lake level rises.

3 The Percent of Downstream Damages Avoided is based on the computed without-project condition damages. The assumptions for without-project conditions damages vary depending on the category.



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Graph 10

6.0 Discussion

6.1 Comparison Between Alternatives

This comparison of alternatives is based on the results of the stochastic and Wet Future Scenario analyses. Table 11 on the following page compares the net benefits and the reduction in flood damages adjacent to the lake for all of the alternatives based on net benefits that were evaluated under the stochastic and scenario analyses. Table 12 provides a summary ranking of the alternatives under the various stochastic and scenario analyses. Data in Table 12 include the net benefits, the percent of damages prevented adjacent to the lake, the percent of costs avoided by the outlet, the peak lake level, the downstream damages avoided for each alternative, annual project costs, first costs, and BCR.

6.1.1 Alternatives within the Basin

Under average future conditions (based on the stochastic analysis), the alternative with the largest annual net benefit is the Expanded Infrastructure Measures alternative. There is little financial risk with this alternative: the incremental protection measures are completed as required and the total project costs are spread over several years' duration. The primary benefits of this alternative are the protection costs that are avoided by keeping water away from features within the perimeter dam. This alternative does not negatively impact the downstream river concentrations, however neither does it decrease the possibility of a natural overflow. A weakness of this alternative is that the protection area is limited to the area within the levee system. There is no assurance that features outside of this levee system will be protected from the rising lake levels.

The Upper Basin Management alternative also shows relatively large net benefits under the stochastic analysis when compared to the outlet alternatives (although it is not economically justified). This alternative does not negatively impact the downstream river concentrations, however neither does it appreciably decrease the possibility of a natural overflow. Additional considerations for this alternative are the feasibility of upper basin storage implementation in prime farmland and the potential social and environmental impacts in the upstream basin.

Under the wet future conditions, the alternatives that have the largest reduction in lake levels have the largest net benefits. Therefore, alternatives within the basin—which do nothing to reduce lake levels—have comparatively low net benefits (when compared to outlet alternatives). Nevertheless, all of the within-the-basin alternatives show a positive net benefit under the Wet Future Scenario.

Construction of the Raise Natural Outlet alternative appears to be economically feasible, however, the actual costs for induced damages may vary from those represented in this analysis. This alternative decreases the possibility of a natural overflow to the downstream river, at the expense of raising the lake level.

Economic Analysis of Devils Lake Alternatives
Table 11

Comparison of Alternatives
(net benefits in millions of dollars)

Description of Alternative	Stochastic Analysis				Wet Future Analysis				Moderate Future 2 Analysis (1455)				Moderate Future 1 Analysis (1450)				Dry Future Analysis			
	Anaylsis No.	Net Benefit Ranking	Net Benefit[1]	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]	Scenario No.	Net Benefit Ranking	Net Benefit	% Flood Damages Reduced[3]
Alternatives within the Basin																				
Upper Basin Management	ST-1	3	-$1.9 [2]	6%	WF-1	9	$0.5	5%	--	--	--	--	--	--	--	--	--	--	--	--
Expanded Infrastructure Measures	ST-2b	1	$1.3	0%	WF-2b	10	$0.2	0%	--	--	--	--	--	--	--	--	--	--	--	--
Raise Natural Outlet	--	--	--	--	WF-11	7	$2.4	0%	--	--	--	--	--	--	--	--	--	--	--	--
Outlet Alternatives																				
West Bay 300 cfs Constrained Outlet	ST-3	5	-$4.2	10%	WF-3	6	$13.3	32%	M2-1	3	-$0.4	14%	M1-1	3	-$5.3	22%	DR-1	2	-$6.0	0%
West Bay 480 cfs Unconstrained Outlet	ST-4	8	-$11.1	26%	WF-4	2	$16.6	56%	M2-2	4	-$2.8	52%	M1-2	4	-$12.1	61%	DR-2	4	-$13.6	0%
Pelican Lake 300 cfs Constrained Outlet	ST-5	6	-$4.9	18%	WF-5	5	$13.6	33%	M2-5	1	$3.1	40%	M1-5	1	-$4.8	61%	DR-5	3	-$7.7	6%
Pelican Lake 480 cfs Unconstrained Outlet	ST-6	9	-$12.4	26%	WF-6	3	$15.0	56%	M2-6	5	-$3.8	52%	M1-6	5	-$14.0	61%	DR-6	5	-$14.7	6%
East End 480 cfs Unconstrained Outlet	ST-10	4	-$3.8 [2]	26%	WF-10	1	$18.3	56%	--	--	--	--	--	--	--	--	--	--	--	--
Combination Alternatives																				
Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	ST-7b	2	-$0.6 [2]	6%	WF-7b	8	$0.8	6%	--	--	--	--	--	--	--	--	--	--	--	--
Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	ST-8b	7	-$5.1	14%	WF-8b	4	$14.3	35%	M2-3b	2	-$0.2	30%	M1-3b	2	-$5.0	24%	DR-3b	1	-$5.9	64%

Note: Where percentages are shown for "Flood Damages Reduced", percentages are always based upon the damages that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with a [2].
[2]Net Benefits without downstream impacts considered. Therefore, actual net benefits would be expected to vary from those shown.
[3]These reduced flood damage percentages pertain only to the features adjacent to Devils Lake

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Economic Analysis of Devils Lake Alternatives
Table 12

Alternatives Ranked by Net Benefits
(costs and benefits in millions of dollars)

Analysis/Scenario Number	Description of Alternative	Annual Net Benefits With Downstream Impacts[1]	Damages Prevented by Project[6] (Percent)	Costs Avoided by Project[6] (Percent)	Highest Lake Level	Downstream Damages Avoided (Percent)	Annual Project Costs	First Costs[2]	BCR
Stochastic Analysis									
ST-2b	Expanded Infrastructure Measures	$1.3	0.4%	23%	1458 [5]	0%	$1.1	$15.2	2.10
ST-7b	Combination 1 - Upper Basin Management and Expanded Infrastructure Measures	-$0.6 [3]	6%	29%	1458 [5]	NA	$3.7	$53.7	0.84 [4]
ST-1	Upper Basin Management	-$1.9 [3]	6%	7%	1458 [5]	NA	$2.7	$39.7	0.29 [4]
ST-10	East End 480 cfs Unconstrained Outlet	-$3.8 [3]	26%	29%	1453 [5]	NA	$7.2	$47.7	0.88 [4]
ST-3	West Bay 300 cfs Constrained Outlet	-$4.2	10%	13%	1456 [5]	1%	$5.8	$71.4	0.28
ST-5	Pelican Lake 300 cfs Constrained Outlet	-$4.9	18%	24%	1455 [5]	1%	$7.8	$97.5	0.37
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.1	14%	38%	1456 [5]	1%	$9.4	$123.9	0.46
ST-4	West Bay 480 cfs Unconstrained Outlet	-$11.1	26%	29%	1453 [5]	-29%	$11.2	$146.7	0.01
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	-$12.4	26%	32%	1453 [5]	-20%	$13.8	$182.7	0.10
Wet Future Scenario									
WF-10	East End 480 cfs Unconstrained Outlet	$18.3	56%	70%	1452	-10%	$9.9	$137.8	2.85
WF-4	West Bay 480 cfs Unconstrained Outlet	$16.6	56%	70%	1452	-6%	$12.2	$148.2	2.37
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	$15.5	56%	70%	1452	2%	$14.7	$183.0	2.06
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$14.3	35%	54%	1456	19%	$11.2	$139.4	2.28
WF-5	Pelican Lake 300 cfs Constrained Outlet	$13.6	33%	45%	1457	19%	$8.3	$97.7	2.62
WF-3	West Bay 300 cfs Constrained Outlet	$13.3	32%	39%	1457	19%	$6.4	$71.4	3.09
WF-11	Raise Natural Outlet	$2.4	0%	0%	1462	22%[7]	$1.1	$15.9	3.24
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$0.8	6%	16%	1460	4%	$6.5	$91.4	1.13
WF-1	Upper Basin Management	$0.5	5%	6%	1460	4%	$2.7	$39.7	1.20
WF-2b	Expanded Infrastructure Measures	$0.2	0.2%	11%	1460	0%	$4.1	$54.8	1.06
Moderate Future 2 Scenario (1455 Peak)									
M2-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$20.2	96%	0%	1452	-1%	$18.4	$232.2	2.10
M2-5	Pelican Lake 300 cfs Constrained Outlet	$3.1	40%	59%	1450	-1%	$8.0	$97.1	1.38
M2-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$0.2	30%	54%	1452	-1%	$10.2	$133.2	0.98
M2-1	West Bay 300 cfs Constrained Outlet	-$0.4	14%	30%	1453	-1%	$5.9	$71.4	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	-$2.8	52%	69%	1448	-44%	$11.7	$148.8	0.76
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	-$3.8	52%	71%	1448	-31%	$14.4	$186.0	0.73
Moderate Future 1 Scenario (1450 Peak)									
M1-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$10.4	97%	0%	1448	-1%	$10.8	$146.2	1.96
M1-5	Pelican Lake 300 cfs Constrained Outlet	-$4.8	61%	45%	1447	-1%	$7.8	$97.1	0.38
M1-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.0	24%	59%	1448	-1%	$8.5	$111.1	0.41
M1-1	West Bay 300 cfs Constrained Outlet	-$5.3	22%	8%	1450	-1%	$5.8	$71.4	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	-$12.1	61%	45%	1447	-26%	$11.4	$149.1	-0.06
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.0	61%	45%	1447	-22%	$13.8	$183.0	-0.01
Dry Future Scenario									
DR-3a	Combination 2 - West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Maximum Infrastructure Protection	$1.7	97%	0%	1448	-2%	$11.9	$162.9	1.15
DR-3b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	-$5.9	64%	38%	1448	-2%	$8.4	$111.1	0.30
DR-1	West Bay 300 cfs Constrained Outlet	-$6.0	0%	0%	1448	-3%	$5.8	$71.4	-0.04
DR-5	Pelican Lake 300 cfs Constrained Outlet	-$7.7	0%	6%	1448	-3%	$7.7	$97.1	0.01
DR-2	West Bay 480 cfs Unconstrained Outlet	-$13.6	0%	0%	1448	-33%	$10.8	$142.8	-0.26
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	-$14.7	0%	6%	1448	-19%	$13.4	$179.4	-0.10

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Where percentages are shown for "Damages Prevented" and "Costs Avoided", percentages are always based upon the damages or costs that would occur in the absence of the project.

[1]The net benefits listed include the downstream impacts, where available. Alternatives where downstream impacts are not available are shown with a [3].

[2] First costs do not include operation and maintenance costs. Natural Resources Mitigation and alternative water treatment are included in first costs.

[3]Net Benefits without downstream impacts considered. Therefore, actual net benefits would be expected to vary from those shown.

[4]Based on benefits without downstream impacts considered. Actual BCR would be lower than those shown.

[5]Based on the 10% chance lake level.

[6]These damages prevented and costs avoided pertain only to the features adjacent to Devils Lake.

[7]Downstream damages would theoretically be reduced by 100% for this alternative. However, this computation of damages avoided includes remaining flow-related damages that are due to local precipitation events.

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The alternatives within the basin have less impact on reducing the flood levels around Devils Lake than the outlet alternatives. These prolonged flooding problems and the associated decision-making processes are extremely stressful for local agencies and residents during this period of high lake levels.

6.1.2 Outlet Alternatives

The study evaluated the economic feasibility of three outlet locations: East End, West Bay, and Pelican Lake. None of the outlet-only alternatives showed positive net benefits under the stochastic analysis. All of the outlet-only alternatives showed positive net benefits under the Wet Future Scenario analysis.

The East End 480 cfs unconstrained gravity outlet had the smallest net negative annual benefit of the outlet alternatives under the stochastic analysis. The unconstrained outlet options (the East End, the West Bay, and Pelican Lake) are more effective at reducing the lake levels than the constrained options. The East End outlet has a higher risk, as it may potentially impact the downstream rivers worse than predicted. Therefore, the East End outlet may not be a cost-effective alternative under the stochastic analysis.

The West Bay and Pelican Lake 300 cfs constrained outlets have larger annual net benefits than the 480 cfs unconstrained outlets under the stochastic analysis. Although the constrained outlets are not economically justified under the stochastic analysis, they may have fewer risks to the downstream rivers than the East End outlet since the water that is released is constrained by downstream water quality and quantity standards.

Under the Wet Future Scenario analysis, the 480 cfs unconstrained outlets provide the largest net benefits of the alternatives evaluated. These outlets are the most effective at reducing the lake levels, and provide a positive net benefit. Again, the East End Outlet shows the largest net benefits. The West Bay and Pelican Lake Outlets also have very large net benefits under the Wet Future Scenario.

Some local agencies and residents may perceive the outlet alternatives as providing the greatest degree of protection to relieve the pressures of the prolonged flooding problems.

6.1.3 Combination Alternatives

Combinations of three projects—West Bay 300 cfs constrained outlet, Upper Basin Management, and Expanded Infrastructure Measures—were analyzed to determine if the net benefits could be increased.

Examination of the results of the stochastic analysis shows that the Expanded Infrastructure Measures by themselves have larger net benefits than when combined with other projects. This indicates that the addition of the West Bay outlet or Upper Basin Management to the Expanded Infrastructure Measures alternative is economically infeasible.

The combination of the West Bay Outlet with Upper Basin Management and Expanded Infrastructure Measures provides a large annual net benefit under the Wet Future Scenario analysis, and is economically justified. However, this combination has a negative net benefit under the stochastic analysis.

The combination with the outlet is more effective at reducing the lake levels, however it carries a high financial risk. The potential negative impacts to the downstream rivers would be less with the outlet combination.

The combinations of Upper Basin Management and Expanded Infrastructure Measures alternatives provide less net benefits under the Wet Future Scenario analysis. Although this combination provides a negative annual net benefit under the stochastic analysis, it is the second largest net benefit of the alternatives evaluated.

Combinations that include other outlets or projects could also be evaluated as potentially feasible options. It is likely that the economic indices for these other combinations would vary in accord with the relationships of those indices for the various outlets when not in combination.

6.2 Sensitivity Analyses

6.2.1 Local Flood Protection Strategies Adjacent to the Lake

The selection of the set of local flood protection measures has a significant impact on the remaining damages and flood damage reduction in the basin. Using the set of most likely action strategies appears to provide the smallest reduction of flood damages. However, the net benefit of the alternatives is also dependent on the cost savings for the flood protection measures.

When combined, the sets of strategies have similar effects on the combined damage reduction and cost savings (except for the set of no protection strategies). Among the three sets of strategies, the set of most likely action strategies can provide the most benefits to the alternatives. The largest benefits are provided using the set of no protection strategies, however, this condition is not likely to be implemented throughout the region (based on implementation of previous protection measures).

By comparison to the other alternatives, the Expanded Infrastructure Measures alternative shows a different pattern of benefits. The pattern of relative benefits seen in Graph 8 and associated with different sets of strategies does not hold when Expanded Infrastructure Measures are evaluated. For Expanded Infrastructure Measures, the maximum protection strategy shows the largest benefits—for other alternatives benefits are largest when no protection is assumed. This highlights the fact that raising the perimeter dikes rather than the roads (in the Expanded Infrastructure Measures area) has larger economic benefit.

6.2.2 Maximum Infrastructure Protection

All of the alternatives that include Maximum Infrastructure Protection have a positive annual net benefit. These alternatives have the largest net benefits and the best BCRs over a range of futures. This signifies that the implementation of the flood protection measures within the basin are economically justified—and may in fact represent the most economically defensible approach to flood control management at the lake. The wetter the future, the more that multiple types of projects are required in the basin to relieve the flooding. This is seen in the combination of maximum infrastructure measures with other projects within the basin, which provides a larger net benefit under the Wet Future Scenario.

6.2.3 Moderate and Dry Future Scenarios

Analysis of the alternatives using drier future climate scenarios indicates that the net benefits are highly correlated with the assumed climate future. Which climate future is assumed also impacts the ranking of the alternatives.

Under the Moderate Future 2 Scenario, the only alternative with a positive net benefit is for the Pelican Lake 300 cfs constrained outlet. None of the alternatives under the Moderate Future 1 or the Dry Future scenarios have a positive net benefit; the alternatives cannot prevent numerous damages because the peak lake levels are 1450 or less.

6.2.4 Erosion of the Natural Outlet

In cases where the projected lake future includes a natural overflow, the sensitivity analysis suggests that economic modeling results **are** sensitive to assumptions regarding the erosion of the natural outlet. If erosion of the natural outlet is included in the analysis, the net benefits of the alternatives will increase.

Although features adjacent to the lake are not affected by the amount of erosion, the downstream features are expected to be impacted more severely when there is erosion of the natural outlet. Impacts would be greatest in the urban areas; the increase in damages being a result of much higher flows during the erosion period. Additional physical and environmental damages that would occur due to the transport of eroded material could be expected to further increase the net benefits of the alternatives. These damages, however, were not included in the analysis.

Glossary

action level – an elevation at which a feature protection action is taken (costs are incurred to construct or implement a flood protection measure) based on a decision made at a prior, lower decision/action level. No decision is required.

Alternative – an overall approach to flood control and management, consisting of a single project or combination of projects. Each alternative is evaluated to determine its economic feasibility and compare its net benefit to that of other alternatives.

Analysis – economic evaluation of various alternatives using either a stochastic (quantitative) or scenario (qualitative) based approach.

BCR (benefit-cost ratio) – a measure of the economic feasibility of a project. The BCR is defined as the benefits divided by the costs. A BCR greater than one indicates that the benefits are greater than costs, which implies that the project is economically justified.

benefit – the value of protection that is provided by a project or a feature protection measure, including the reduction of damages and the cost savings. Benefits are negative in cases where project implementation increases the damages to a particular feature. In some analyses, negative benefits are tallied as costs; for this Economic Analysis they are recorded in the benefits column along with any positive benefits.

cost – an amount paid to construct a project that will prevent potential damages, or an amount paid to mitigate future damages. The term is also sometimes used to refer to damages induced by a project.

Cost-effective – designation for a set of feature protection strategies that are based on the maximum net benefits, i.e., benefits minus costs.

Cost-effectiveness – a term used to compare alternatives in which not all of the benefits are quantifiable. The alternative that provides the most benefits for the investment of Federal dollars refers to the plan with the largest cost-effectiveness.

damage – loss of value to infrastructure or features due to flooding or increased concentrations in the water.

decision level – an elevation at which a decision is required for protection of a feature, but no action is taken as a result of the decision (no decision levels were identified in this study).

decision/action level – an elevation at which a decision is made for protection of a feature and an action may be taken (depending on the decision made). In some cases, later actions may also be taken at subsequent, higher action levels based on the decision made at the original decision/action level.

decision tree – a graphical representation that indicates the lake elevations at which decisions and actions would be required for each feature and the options at those levels.

economically justified / economically feasible – an alternative is said to be economically justified or economically feasible if it has a positive net benefit—the benefits of a project minus the costs for construction and operation of the project are greater than zero.

Features – physical entities or groups of entities that would be susceptible to damage from the rising lake or from flows released from the lake (for example, Community of St. Michael, Highway 20 between Highway 57 and Tokio, Grahams Island State Park, Rural Areas adjacent to Stump Lake, downstream municipal water treatment facilities, etc.).

future – refers to an event that will happen in a time period that is to follow the current situation.

Future – one of four categories of the stochastically generated traces. These Futures each center around an average peak lake level. For example, the Wet Future comprises 10% of the stochastically generated traces and has an average peak lake level of 1461.1. For the purposes of this study, each of these Futures is represented by one trace.

Infrastructure – individual structures and transportation, communication, and utility networks. Infrastructure may include roads, rail lines, homes, businesses, utilities, etc.

Natural outlet – the waterway through which water naturally flows out of the Devils Lake basin, through the Tolna Coulee, and to the Sheyenne River. The term is at times used to refer to the location at the rim of the Devils Lake basin over which flow would first occur from the basin.

Natural overflow – flow that leaves the Devils Lake basin through the natural outlet.

Net benefit – the benefits of a project minus the costs for construction and operation of the project. Project selection will typically favor the project with the largest net benefit, although risk and effectiveness must also be considered.

Outlet – a flood control project that removes water from Devils Lake and directs it into the Sheyenne River (for example, West Bay 300 cfs constrained pumped outlet or East End 480 cfs unconstrained gravity outlet).

project – a flood control measure that reduces the regional damages that would otherwise be caused from the rising lake—either by reducing the lake level, reducing the downstream impacts, or protecting the features adjacent to the lake. For example, upper basin storage, infrastructure protection, a pumped or gravity outlet, or an Raise the Natural Outlet are each referred to as a project.

project cost – the costs related to installation, operation, and maintenance of a project, including costs for induced damages, and for environmental monitoring and mitigation of environmental damages.

scenario – a conditional forecast based on certain climatic and hydrologic assumptions. The assumptions inherent in the forecast determine the lake levels and related downstream flows. The scenarios defined in this study include a wet future, two moderate futures, and a dry future.

set of strategies – a selection of flood response measures that is universally assumed for all features. The four sets of strategies include: set of most likely action strategies, set of cost-effective strategies, set of no flood protection strategies, and set of maximum protection strategies at the first action level. In most cases, the set of strategies will be implemented independent of a flood control project.

stochastic – a term used to describe the probabilistic determination of future lake levels, based on the assumption of a stationary climate. The stochastic analysis generates the 10,000 traces of 50-year future lake levels.

strategy – a flood response measure specific to a particular feature around the lake (for example, raise Highway 2 above the current flood level, or relocate homes in Churches Ferry).

trace – a 50-year sequence of projected lake levels or river characteristics (concentrations, flows, etc.).